35651

Intake
R4 SC
Wateree

WATEREE STATION

316 (a) & (b) DEMONSTRATION

SOUTH CAROLINA ELECTRIC & GAS COMPANY

COLUMBIA, SOUTH CAROLINA

ENWRIGHT ASSOCIATES, INC.
CONSULTING ENGINEERS
GREENVILLE - COLUMBIA - SUMMERVILLE
SOUTH CAROLINA

enwright associates

ENGINEERS

March 30, 1977

rec'd 8-11

South Carolina Electric & Gas Company
Post Office Box 764
Columbia, South Carolina 29218

ATTENTION: Mr. R. M. Webb

Subject: South Carolina Electric & Gas Company
316 (a) & (b) Demonstration
Wateree Station
NPDES Permit No. SC0002038

Gentlemen:

We have completed the following report on thermal and biological studies performed by Enwright Associates and your staff in response to the provisions of NPDES Permit No. SC0002038 to submit thermal and biological demonstrations in conformance with Sections 316 (a) and (b) of PL 92-500. These studies were carried out between January, 1975 and February, 1977.

This report concludes that:

1. The Wateree Station is eligible for alternative, less stringent, thermal effluent limitations under Section 316 (a) of PL 92-500 and this document demonstrates that such alternative limitations are warranted.

2. It has been demonstrated that the Wateree Station cooling water intake structure exerts minimal environmental impact and utilizes Best Technology Available as required by Section 316 (b) of PL 92-500.

We appreciate the courtesies and cooperation of your staff and all agencies and individuals who have contributed to the completed report.

We are available to review our findings, conclusions and recommendations at your convenience and to assist you with presenting this report to the appropriate State and Federal agencies.

Very truly yours,

ENWRIGHT ASSOCIATES, INC.

W. Bowman Crum, Jr.

W. Bowman Crum, Jr.
Manager, Biological Laboratories

F. P. Williams Jr

F. Pierce Williams, Jr.
Vice-President

WATEREE STATION

316 (a) AND (b) DEMONSTRATION

South Carolina Electric & Gas Company

Columbia, South Carolina

March 1977

ENWRIGHT ASSOCIATES, INC.
Consulting Engineers

Greenville - Columbia - Summerville
South Carolina

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CHAPTER I

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. Summary

This document is South Carolina Electric and Gas Company's 316 (a) and (b) demonstration for the Wateree Station located on the Wateree River southeast of Columbia, South Carolina. It presents the results of thermal and biological studies designed to evaluate the influence of the operation of the Wateree Station upon the aquatic environment of the Wateree River. This report is based principally on research projects conducted by South Carolina Electric and Gas Company, Enwright Associates, Inc. and the South Carolina Wildlife and Marine Resources Department.

B. Conclusions

The major conclusion of this document is that operation of Wateree Station is such that the protection and propagation of a balanced indigenous aquatic community in and on the Wateree River is assured. This major conclusion is supported by the following:

1. Species composition, relative abundance of important species and diversity of the indigenous fish community are not adversely affected by Station operation.
2. Growth and body condition of important fish species are not impaired by operation of the Station.
3. Successful reproduction by important fish species is not hindered by Station operation.

4. The thermal discharge does not enhance frequency of occurrence or intensity of infestation of fish parasites and diseases.

5. No rare or endangered fish species are known to occur in the area.

6. The striped bass is the only major fish species in the area with pelagic eggs and larval stages that would be susceptible to condenser cooling system and thermal plume entrainment in significant numbers. It has been demonstrated by state agency studies that the Wateree River is not an important spawning area for striped bass. This information precludes the possibility of significant detrimental effects of entrainment on the fish community.

7. Fish impinged on intake screens consist primarily of threadfin shad which have been killed or immobilized by low ambient temperatures during colder months. Impingement rates of other species are extremely low and have no effect on the indigenous community.

8. Station operaton has not resulted in significant increases in abundance of nuisance species or reduction in abundance of any valuable species. Substantial changes in community heterogeneity have not occurred.

The Wateree Station is eligible for alternative, less stringent, thermal effluent limitations under Section 316 (a) of PL 92-500 and this document demonstrates that such alternative limitations are warranted.

It has been demonstrated that the Wateree Station cooling water intake structure exerts minimal environmental impact and utilizes Best Technology Available as required by Section 316 (b) of PL 92-500.

C. Recommendations

It is recommended that the thermal effluent limitations imposed in National Pollutant Discharge Elimination System Permit No. SC0002038 be modified to conform to the present operating parameters of the Wateree Station as described in Chapter IV of this report. Also, it is recommended that it be determined that the cooling water intake structure at the Wateree Station utilizes Best Technology Available.

CHAPTER II

INTRODUCTION

A. Legal Background

Under the 1972 Amendments to the Federal Water Pollution Control Act (PL 92-500) operators of steam electric power generating units must comply with applicable technology based effluent limitations promulgated by the Administrator of the U.S. Environmental Protection Agency. These limitations, Effluent Guidelines and Standards, are published as 40 C. F. R. Part 423, October 8, 1974. The Wateree Station units are classified as "old units" as defined in the Effluent Guidelines and Standards and are thus exempt from the "no discharge of heat" limitations. In addition, these regulations require compliance with effluent limitations calculated to achieve water quality standards as required under Section 301 (b) (1)(c) of PL 92-500. An exemption from the limitations on the discharge of heat is available through a successful demonstration under Section 316 (a) of PL 92-500.

The State of South Carolina water quality standards require that the temperature of receiving waters not exceed 32.2°C (90°F) and that after passing through an adequate zone of mixing be no more than 2.8°C (5°F) above that of water unaffected by the heated discharge. The zone for mixing is limited to not more than 25 percent of the cross sectional area and/or volume of flow of the stream and to one-third of the surface area measured from shore to shore. Due to the nature of the receiving

B. Site Location and Description

The Wateree Station is a two unit, coal fired generating facility which is located on the right (west) bank of the Wateree River in Richland County, South Carolina (Figure 1). The Station site is about 30 miles northeast of Columbia (pop. 113,542) and is 28 miles from Sumter (pop. 23,895), 33 miles from Orangeburg (pop. 13,252 and 4.5 miles from Eastover (pop. 817). The site coordinates are approximately latitude 33° 49' 42" and longitude 80° 37' 14". The Station is located just off U. S. Highway 601 about 1.8 miles northeast of the intersection of S. C. Highway 48 and U. S. Highway 601.

The plant lies at river mile 10.5 upstream of the confluence of the Wateree and Congaree Rivers which forms the Santee River and is 65.7 miles downstream of Wateree Dam. The Wateree River (Catawba-Wateree System) drainage area at the Station is approximately 5,590 square miles (14,480 km^2). The flow is regulated by Duke Power Company's hydroelectric plant at Wateree Reservoir which has a usable capacity of 3,794,000,000 cubic feet (79,126,000 m^3). Wateree Reservoir has a surface area of 13,710 acres. The average flow in the river at the Station (USGS Gage) is 6326 cfs (USGS, 1975).

The Wateree River Basin is located in the Atlantic Coastal Plain physiographic province. The topography of this area is nearly level to moderately sloping. The Station is located on the river's flood plain at an elevation of 108 feet above sea level. The mean river elevation is 89.8 feet above sea level. The right (west) bank is a narrow flood

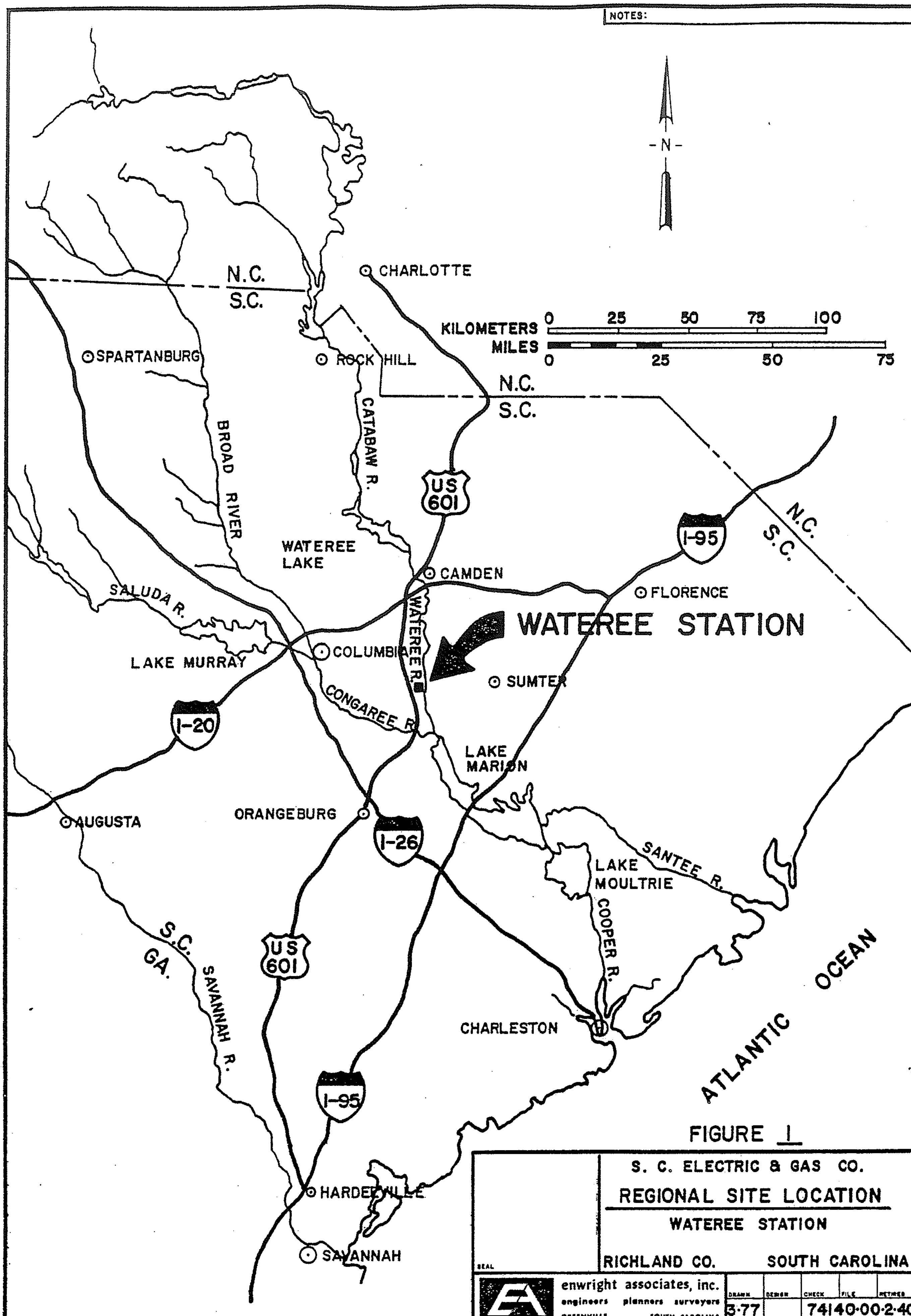

FIGURE 1

S. C. ELECTRIC & GAS CO.

REGIONAL SITE LOCATION

WATEREE STATION

RICHLAND CO. SOUTH CAROLINA

SEAL

enwright associates, inc.
engineers planners surveyors
GREENVILLE, SOUTH CAROLINA

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plain interrupted frequently by bluffs. Along the left (east) bank is a much more extensive swamp which extends five to seven miles from the main river channel.

The climate of the area is warm temperate and is characterized by warm, wet summers and mild, dry winters. The mean annual precipitation of 44 inches is well distributed throughout the year with about 33 percent of the annual total coming in the summer months, 20 percent in the fall, 22 percent in the winter and 25 percent in the spring. According to data compiled by the National Weather Station at the Columbia Metropolitan Airport, the nearest climatological data station, the mean maximum temperature during summer is 91°F and the mean minimum is 69°F. Fall is the sunniest time of the year with a mean maximum temperature of 76.5°F and a mean minimum of 51.8°F. Winters are mild with only one-third of the days between December and February having minimum temperatures below freezing. The mean maximum during winter is 58.2°F and the mean minimum is 34.5°F. Spring is the most changeable season with a mean maximum temperature of 76°F and the mean minimum is 51°F. The prevailing winds are southwesterly for most of the year with a mean speed of 6.9 mph; however, during September and October the winds are generally from the northeast at a mean speed of 6.3 mph. The mean relative humidity is between 85 and 90% for both summer and fall and drops to 80% during winter and continues to decrease into spring when the mean relative humidity is 70%.

CHAPTER III

PLANT OPERATING DATA

A. General

The two coal fired units at Wateree Station are each rated at 360 MWe for a total Station production capacity of 720 MWe. Condenser cooling water is supplied by four circulating water pumps having a combined capacity of 758 cfs (340,000 gpm). Condensers are mechanically cleaned using a system of continuously circulating sponge rubber balls (Amertapp). The heated effluent, when necessary, can be cooled prior to discharge by mechanical forced draft cooling towers. The discharge can be directed to the cooling water intake for "closed-cycle" cooling, or to the river for "helper" or "once-through" cooling (Figure 2).

Commercial operation of Units 1 and 2 began on September 10, 1970 and December 22, 1971, respectively. Since commercial operation began, the Station has operated at a monthly average production capacity of 348.5 MWe, or 48.4% of the maximum rated capacity. Table 1 describes the actual and projected production capacity of the Station from 1970-1981. Based on this historical average production, Wateree Station can be classified as a cycling load station (USEPA, 1974). A typical production day consists of cycling production to near maximum capacity during peak demand periods and reducing production levels during low demand periods. Wateree Station is projected to operate from 1977 through 1981 at an average capacity of 65.5%.

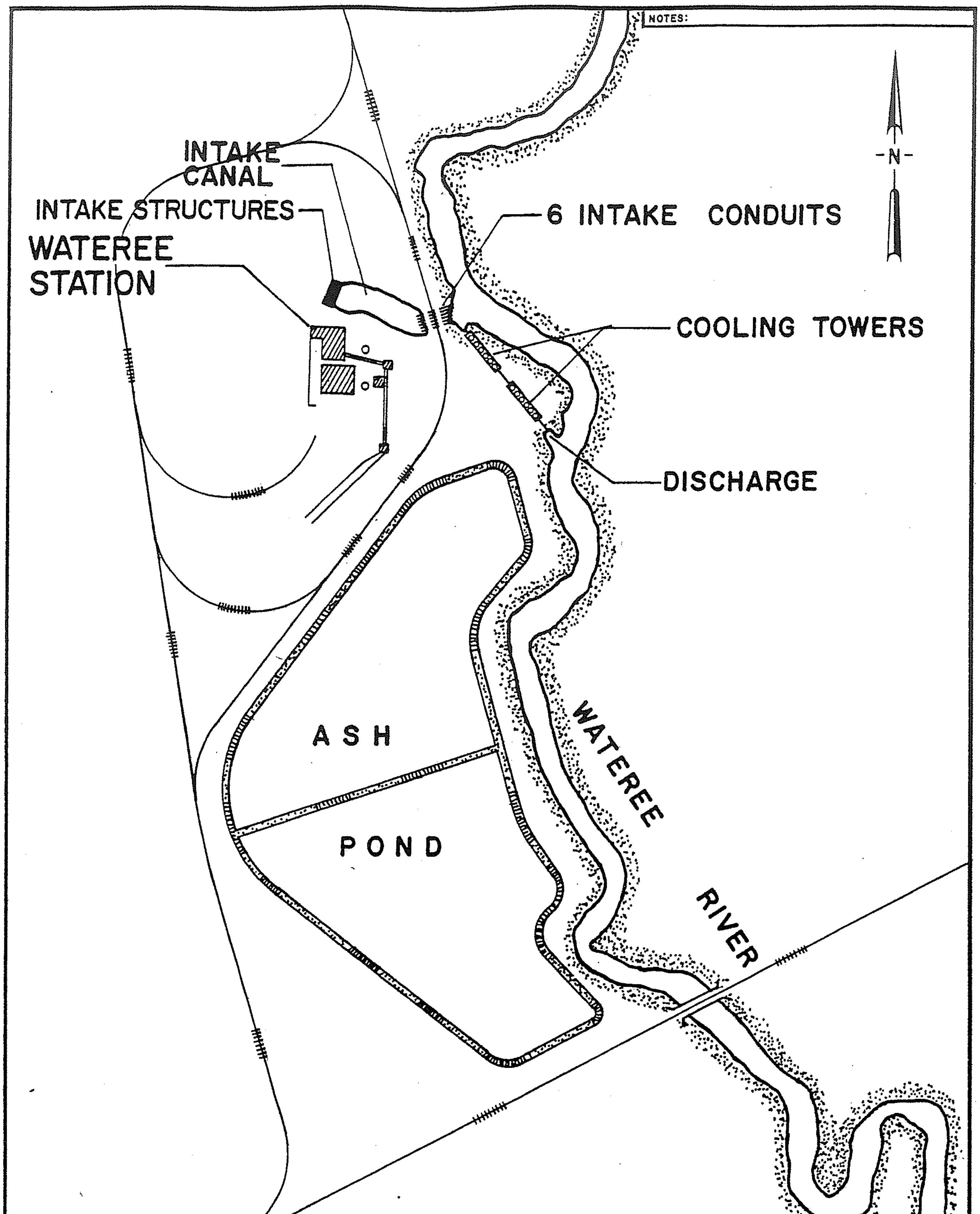

FIGURE 2

PLOT PLAN

SCE&G WATEREE STATION

RICHLAND COUNTY SOUTH CAROLINA

REV.	DATE	BY	DESCRIPTION	APP.

REVISION

SEAL

enwright associates, inc.
engineers planners surveyors
GREENVILLE, SOUTH CAROLINA

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Table 1. Actual and projected Wateree Station production loads from 1970 to 1981.

Year	% Maximum Production Load Actual	Projected
1970	20.0	No projection
1971	65.5	78.0
1972	60.8	68.0
1973	46.1	54.0
1974	36.5	55.0
1975	51.3	58.0
1976	58.4	56.0
1977	-	74.0
1978	-	75.1
1979	-	70.0
1980	-	61.5
1981	-	47.1

The daily average production load during each month of 1976 is included in Table 2. Also included are data on condenser inlet/outlet temperatures, discharge temperatures and river temperatures measured approximately 0.8 miles below the thermal discharge.

During the operational life of Wateree Station, 39 emergency shutdowns have occurred through December 1976. The majority (36) of these emergency shutdowns occurred prior to 1975, and reflect initial operational problems that have now been largely resolved. Since 1975, six total plant shutdowns have occurred, which should be representative of normal Station operation.

B. Intake

The Wateree Station cooling water intake is located at the end of an excavated intake canal approximately 150 feet wide and 1,000 feet from the Wateree River. Water passes through six 72 inch diameter conduit pipes from the river to the canal and intake structure (Figure 2). A bar screen prevents large debris from entering the Station. Traveling water screens (3/8 inch mesh), located approximately 10 feet behind the trash racks, prevent smaller material, such as leaves, from entering the Station. Plan and cross section views of the intake are shown in Figures 3 and 4. The eight traveling water screens (two screens per circulating water pump) activate in unison based on a pressure drop across the screens, and automatically rotate to remove trash and any impinged organisms. The impact of this intake on fish in the Wateree River is discussed in Chapter V.

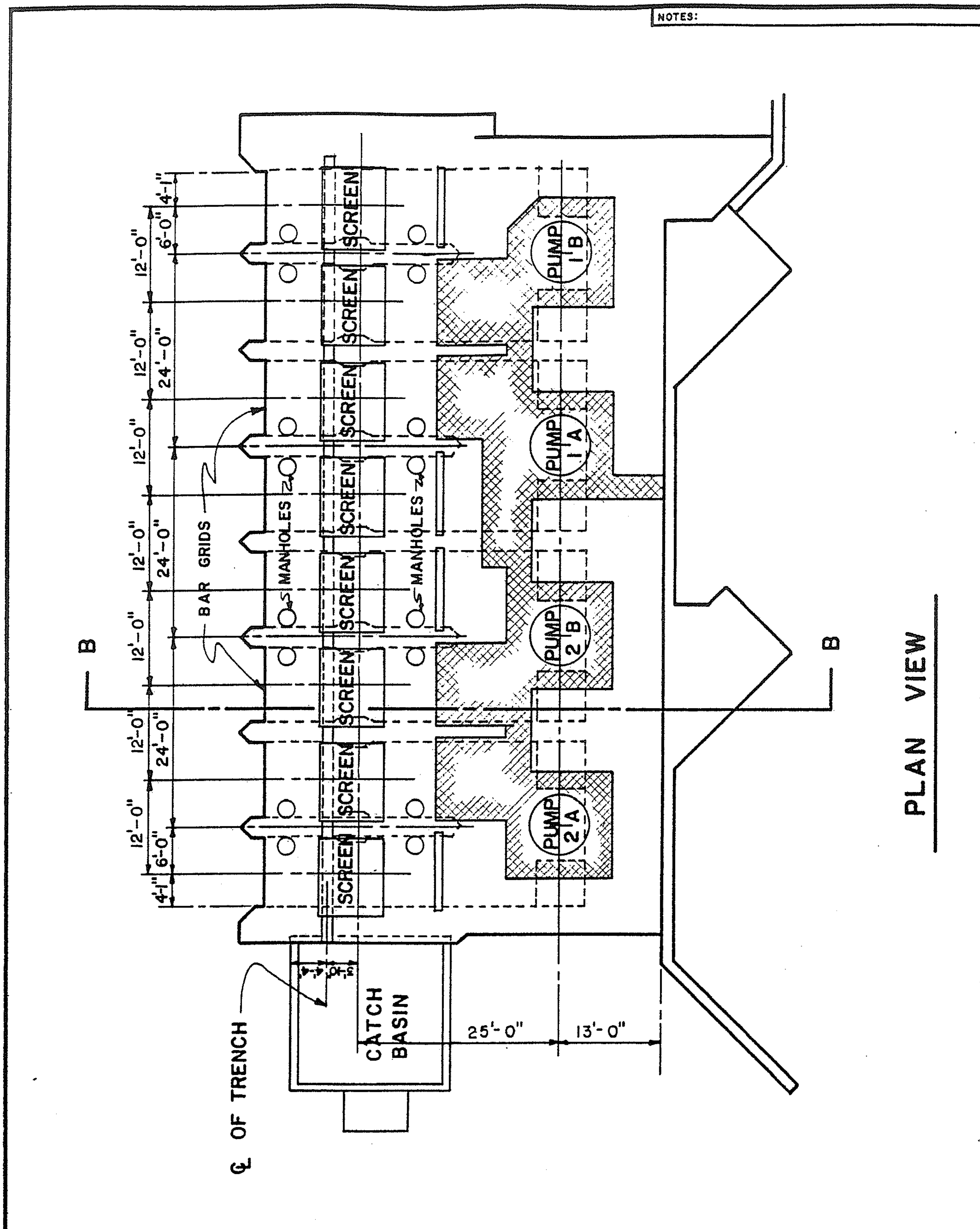
Table 2. Wateree Station plant operating data for 1976.

Month	Primary Cooling Mode a/ Open, Helper	Daily Average Gross MWe Production MWe	Daily Average b/ River Flow cfs	Condenser Temperatures: Daily Average Inlet °F (°C)	Condenser Temperatures: Daily Average Outlet °F (°C)	Daily Average Discharge Temperature °F (°C)	Daily Average Station Discharge Δ T °F (°C)	Daily Average Temperature 0.8 Miles Below The Discharge °F (°C)	Daily Average Δ T 0.8 Miles Below the Discharge °F (°C)
January	Open 100%	483	8183	46.7 (8.2)	67.2 (19.6)	65.0 (18.3)	18.3 (10.2)	48.6 (9.2)	1.9 (1.1)
February	Open 100%	458	7539	51.5 (10.8)	71.9 (22.2)	66.1 (18.9)	14.6 (8.1)	55.1 (12.8)	3.6 (2.0)
March	Open 100%	251	5834	58.3 (14.6)	75.8 (24.3)	71.9 (22.2)	13.6 (7.6)	61.4 (16.3)	2.1 (1.2)
April	Helper 50%	488	3821	65.9 (18.8)	85.3 (29.6)	82.9 (28.3)	17.0 (9.4)	71.4 (21.9)	5.5 (3.1)
May	Helper 55%	444	3851	71.0 (21.7)	90.1 (32.3)	85.2 (29.6)	14.2 (7.9)	74.6 (23.7)	3.6 (2.0)
June	Open 97%	480	7370	76.4 (24.7)	93.0 (33.9)	93.1 (33.9)	16.7 (9.3)	76.7 (24.8)	0.3 (0.2)
July	Open 90%	519	5895	81.6 (27.6)	99.4 (37.4)	94.7 (34.8)	13.1 (7.3)	85.8 (29.9)	4.2 (2.3)
August	Open 55%	526	2774	82.3 (27.9)	103.8 (39.9)	98.9 (37.2)	16.6 (9.2)	85.8 (29.9)	3.5 (1.9)
September	Helper 77%	417	2634	79.1 (26.2)	99.9 (37.7)	88.9 (31.6)	9.8 (5.4)	80.7 (26.3)	1.6 (0.9)
October	Open 100%	283	7738	68.3 (20.2)	85.0 (29.4)	86.5 (30.3)	18.2 (10.1)	70.4 (21.3)	2.1 (1.2)
November	Open 100%	337	6870	54.9 (12.7)	73.2 (22.9)	73.6 (23.1)	18.7 (10.4)	59.7 (15.4)	4.8 (2.7)
December	Open 100%	620	9304	50.8 (10.4)	70.4 (21.3)	No Data	No Data	No Data	No Data

a/Percent time in the Mode noted.

b/ Source: USGS Water Resources Data for South Carolina; 1975, 1976, Provisional Records for October - December of Water Year 1977.

NOTES:



REV.	DATE	BY	DESCRIPTION	APP.

REVISION

SEAL

FIGURE 3

COOLING WATER INTAKE

SCE&G WATEREE STATION

RICHLAND COUNTY SOUTH CAROLINA

enwright associates, inc.
engineers planners surveyors
GREENVILLE, SOUTH CAROLINA

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DATE	SCALE	DWG. NO.		

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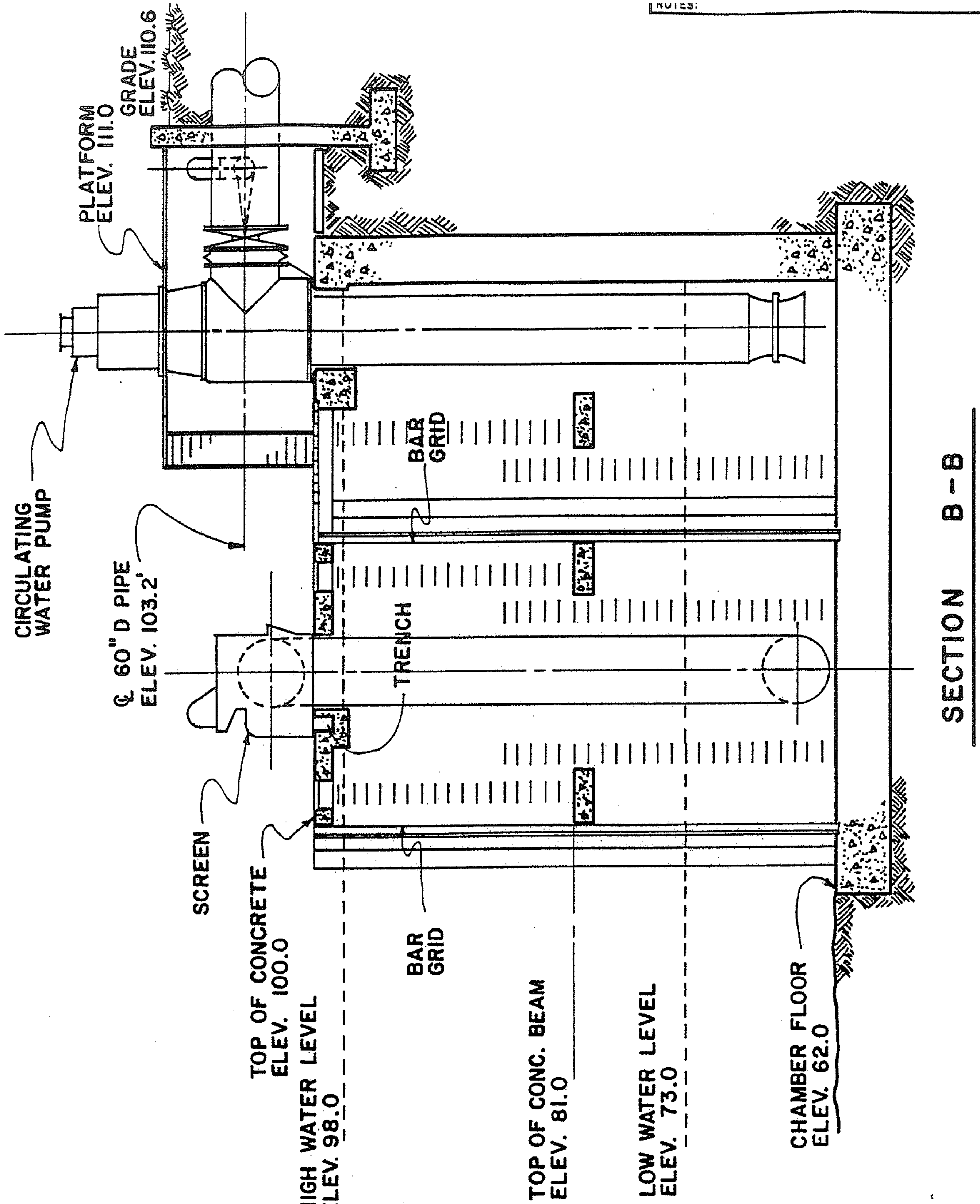

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FIGURE 4

COOLING WATER INTAKE

SCE&G WATEREE STATION

RICHLAND COUNTY — SOUTH CAROLINA

enwright associates, inc.
engineers planners surveyors
GREENVILLE, SOUTH CAROLINA

DRAWN	DESIGN	CHECK	FILE	RETIRED
DATE	SCALE	DWG. NO.		

Each generating unit utilizes two circulating water pumps. Each pump has a rated capacity of 85,000 gpm or 189 cfs. When all four pumps are operating, the time required to pass through the Station from the intake screens to the point of discharge is approximately five minutes. Based on plant operating data collected during 1976, the average condenser temperature rise experienced during this five minute period is 10.6°C (19.0°F).

In order to assist in the evaluation of the impact of the cooling water intake on fish in the Wateree River, intake velocity measurements were made during periods of maximum cooling water flows. These measurements were made during river water flows and subsequent elevations at the intake screens that were near the expected extremes (1400 cfs to 9740 cfs). A Price patterned (Teledyne-Gurley) or an electromagnetic (Marsh-McBirney) current meter was used to measure velocities at two or three equidistant points across each of eight screens and at two foot depth intervals from surface to bottom. The actual point of velocity measurement was at the face of the bar screens, as the face of the traveling water screens was not accessible for measurements. The average velocity measured at the intake structure was 0.5 fps, with a maximum measured velocity of 1.5 fps at any screen. A summary of the field data is contained in Appendix A.

C. <u>Discharge</u>

The thermal effluent at Wateree Station is normally discharged into Wateree River approximately 1300 feet downstream of the cooling water intake. However, by raising and lowering appropriate gates in the cooling tower basin, the heated effluent can be discharged from the north end of the basin (Figure 2) into the cooling water intake for a "closed cycle" operating mode. This operating mode has not been utilized for any significant period, except for testing, during the operational life of the Station.

Historically, the primary operating modes for the Wateree Station cooling towers have been "once through" and "helper." The "helper" mode can be adjusted as necessary by turning the 18 forced draft fans on or off while pumping water to the top of the towers. During 1976, the cooling towers were utilized from April through September. However, during this period, optimum cooling tower operation was not possible as operational problems due to equipment failure and lightning storm damage prevented normal tower operation during June - August.

The temperature reduction that can be expected during cooling tower operation was evaluated by performing a multiple regression analysis of plant operating and U. S. Weather Bureau (Columbia) data. This analysis included data from the period of April through September 1976, when cooling towers were intermittently operated at Wateree Station. The variables used for this analysis included daily average gross MWe production, the number of generating units operating, the condenser cooling water flow, the daily average condenser inlet and outlet temperature (cooling tower inlet temperature), the number of cooling tower pumps, the number of cooling tower fans, daily average relative humidity, daily maximum dry bulb temperature and cooling tower discharge temperature.

This regression analysis also was used to predict the maximum condenser ΔT when both generating units are operating at their rated capacity (720 MWe total). Daily average plant operating data from April through September, 1976 were used for this analysis. Daily average Station production ranged up to 663 MWe during this period. Days with average production loads of less than 360 MWe total were excluded from the analysis, as both units cannot operate continuously at loads of less than 180 MWe each.

The maximum condenser ΔT, based on the upper limit of the 95% confidence interval ($p \leq 0.05$), is predicted to be 15.0°C (27.0°F) at the rated production capacity of 720 MWe. Under maximum cooling tower operation (18 cooling tower fans and 4 pumps), this ΔT is predicted ($p \leq 0.05$, lower limit of the 95% confidence interval) to be reduced to a maximum of 11.1°C (20.0°F) and a minimum of 7.9°C (14.2°F). At the expected maximum ambient temperature of 30.5°C (86.9°F) (Table 5 and Chapter IV.A page 24) and full plant production, the maximum discharge temperature during cooling tower operation is predicted to be 41.6°C (106.9°F), while the minimum discharge temperature is expected to be 37.7°C (101.1°F).

CHAPTER IV

ENVIRONMENTAL DATA

A. Physical Description - Wateree River

The Wateree River is 76.2 miles in length from the Wateree Lake Dam to its confluence with the Congaree River (USGS, 1975). The Wateree Station thermal discharge is approximately 10.5 miles upstream from the confluence of the Wateree and Congaree Rivers (Figure 1). The width of the river during average flow is estimated to be 250 feet.

At the estimated average river width of 250 feet, approximately 2300 acres surface area are covered by the river during periods of average flow. The area below the Wateree Station thermal discharge is approximately 318 acres or 13.8% of the total area available between the Wateree Dam and confluence with the Congaree River. During periods of heavy rainfall and subsequent runoff, or large releases from Wateree Dam, the river overflows its banks and floods into adjacent swamps. The surface area above and below Wateree Station is much larger during these periods.

With the average annual flow of 6326 cfs (USGS, 1975), the theoretical retention time from Wateree Dam to the Congaree River is 1.9 days, assuming a mean depth of 10 feet and an estimated volume of 23,000 acre-feet. During the 7-day 10-year low flow of 800 cfs (W.M. Bloxham, U. S. Geological Survey, Personal Communication, January, 1977), and at an assumed mean depth of 5 feet, this time increases to 7.2 days. Since the Wateree Station thermal discharge is approximately 10.5 miles above the confluence with the Congaree River, the retention times for this 10.5 mile reach can be proportionally reduced from that of the entire 76.2 mile reach to 0.3 and 1.0 days, respectively, for average and 7-day 10-year low flows. The Station utilizes 758 cfs or 12% of the average annual flow and 95% of the 7-day 10-year low flow for condenser cooling.

A greater appreciation of the physical characteristics of the Wateree River can be developed by examining the daily changes in water elevation. The river has been highly regulated since 1929 by Wateree Dam, 65.7 miles upstream, which was built for hydroelectric power generation by Duke Power Company. Water elevations at the Wateree Station are therefore primarily dependent on releases from Wateree Dam, which are in turn dependent on available water and electrical demand. The complexity of factors governing releases at Wateree Dam result in an irregular, but at times, pronounced daily change in water elevation in the Wateree River.

Records made at the U. S. Geological Survey recording gage on the Wateree River near the Wateree Station intake (USGS Eastover Station, #02148315) during July through September 1976, a period with 3768 cfs daily average flow, reveal a maximum daily change in water elevation of 6.75 feet, with elevation changes during any week of up to 8.27 feet (Table 3). The weekly range in water elevations during this period averaged 7.05 feet. During October through December 1976, a period with 7971 cfs daily average flow, USGS records indicate a maximum daily change in water elevation of 6.99 feet, with changes during any week of up to 10.96 feet. The weekly range in water elevations averaged 3.68 feet during the October-December period. Therefore, water elevations in the Wateree River can be expected to vary up to 7 feet from day to day and up to 11 feet during any week, based on the above data covering periods of low to above average flows in the river.

The range of ambient water temperatures experienced at the Wateree Station can be estimated from USGS continuous temperature records from the recording station immediately upstream from the Station cooling water intake. Table 4 indicates that monthly average ambient temperatures recorded by USGS during the Station's six years of operation range from a mean low of 10.5°C (50.9°F) in February to a mean high of 28.2°C (82.8°F) in August. The minimum and maximum recorded ambient temperatures as noted in Table 5 are 3.5°C (38.3°F) and 33.5°C (92.3°F), respectively, and were recorded in Water Year 1971. However, subsequent USGS publications do not recognize these extremes (USGS, 1972-1976) and the expected temperature extremes are 5.0-30.5°C (41.0-86.9°F).

Based on available historical data from the USGS, the Wateree River is approximately 1.5°C (2.7°F) warmer than the Congaree River. The data in Table 6 were collected on the Congaree River near Ft. Motte, 1.9 miles above the confluence with the Wateree River, and indicate that ambient temperatures in the Wateree River have been as much as 6.0°C (10.8°F) warmer than the Congaree. These data demonstrate that temperatures in the Wateree River ranged from 1.5°C (2.7°F) cooler to 6.0°C

Table 4. Wateree Station monthly average ambient water temperatures (°C) for water years (October-September) 1971-1976.

Month	Water Year 1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	Six Year Mean
Oct	24.0 a/	23.5 a/	21.5	23.0	20.0	22.5	22.4
Nov	14.5 a/	14.5 a/	16.5	17.0	16.0	17.5	16.0
Dec	10.5 a/	12.5	11.5	12.5	10.0	12.0	11.5
Jan	9.5 a/	13.0 a/	10.0 a/	13.0 a/	10.2 a/	8.5	10.7
Feb	7.5 a/	No data	10.0 a/	12.5	11.5 a/	11.0 a/	10.5
Mar	11.5	14.0 a/	14.5	15.0	14.7 a/	16.0	14.3
Apr	16.5 a/	18.5 a/	17.0 a/	18.5 a/	17.0 a/	19.5 a/	17.8
May	21.5	22.0	22.0	23.5	22.5	22.5	22.3
Jun	25.5	24.5	25.5	27.0	26.0	24.5	25.5
Jul	27.5 a/	27.5	28.5	28.0	27.0	28.0 a/	27.8
Aug	28.0	29.0	29.0	28.0	28.0	27.5 a/	28.2
Sep	27.0	27.0	28.0	25.5	26.5	25.5 a/	26.6

a/ Average which did not include a full month's data.

Source: United States Geological Survey, Water Resources Data For South Carolina; 1971, 1972, 1973, 1974, 1975 and 1976.

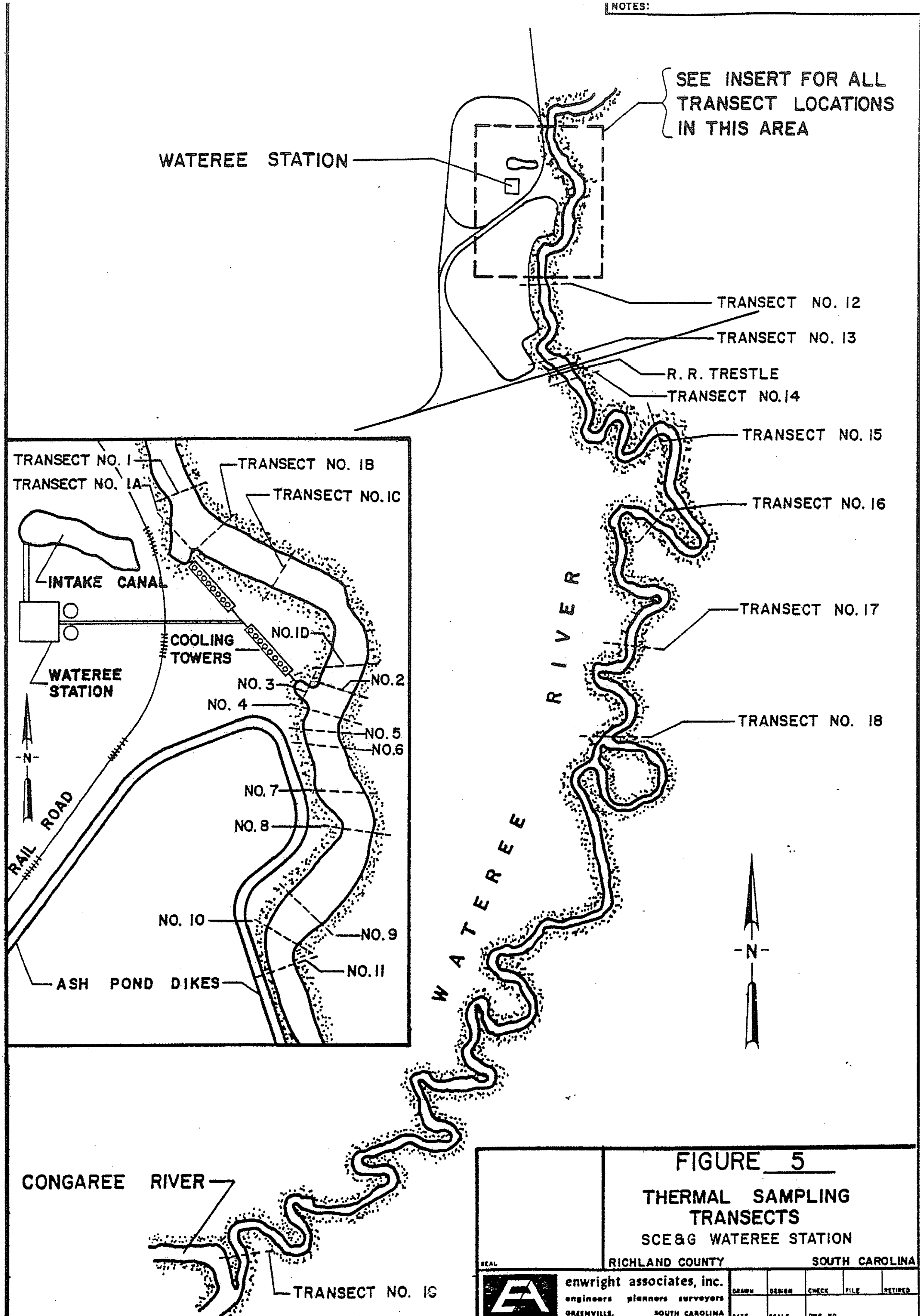


FIGURE 5

THERMAL SAMPLING TRANSECTS

SCE&G WATEREE STATION

RICHLAND COUNTY SOUTH CAROLINA

b. Mathematical Model

A thermal discharge model developed by Sill and Schetz (1973) was used to predict isotherm areas for the Wateree Station thermal discharge. This model includes initial dilution and turbulent mixing in the near field as well as surface heat transfer in the far field. A unique characteristic of the model is that it accounts for free stream boundedness, i.e., that there is only a finite amount of ambient fluid available for dilution. Results from and descriptions of this model have been presented a number of times (Sill and Schetz, 1973; Sill and Schetz, 1975a; Schetz *et al.*, 1975b).

The model has been validated by a series of laboratory tests which included both heated and unheated discharges at a number of temperature and velocity rates. The model was later applied to actual prototype situations (Schetz *et al.*, 1975a; Sill and Schetz, 1975b; Schetz, *et al.*, 1976) with good agreement.

In particular, the near field analysis uses the mass, momentum and energy equations for the discharge and ambient flows. Since the minute details of this complex flow situation are not well known, an integral or control volume approach is used. The control volumes are chosen such that the bounding walls are assumed vertical and parallel, and the free surface is of uniform depth across the entire channel. The jet is initially discharged at, and along the near shore with the assumption that it retains a rectangular cross section with varying width to height ratio and size as it proceeds downstream. A criteria are based on the highly unlikely combinations of maximum condenser ΔT and minimum cooling tower efficiency during maximum ambient river temperatures:

Condenser ΔT at Maximum Production (720 MWe)

1. Maximum Condenser ΔT = 15.14°C (upper limit of the 95% C.I., $p \leq 0.05$)

2. Minimum Condenser ΔT = 11.00°C (lower limit of the 95% C.I., $p \leq 0.05$)

Cooling Tower Discharge Temperature Reduction

3. Maximum Efficiency = 15.14 - 12.13°C = 3.01°C Discharge ΔT (upper limit, 95% C.I., $p \leq 0.05$)

4. Minimum Efficiency = 15.14 - 4.0°C = 11.14°C Discharge ΔT (lower limit, 95% C.I., $p \leq 0.05$)

Condenser ΔT at Average Production Predicted by SCE&G Through 1981 (472 MWe)

5. Maximum Condenser ΔT = 11.3°C (upper limit, 95% C.I., $p \leq 0.05$)

Cooling Tower Discharge Temperature Reduction During Average Plant Production Predicted by SCE&G Through 1981 (472 MWe)

6. Minimum Efficiency = 11.3 - 4.0°C = 7.3°C Discharge ΔT (lower limit, 95% C.I., $p \leq 0.05$)

2. Results

a. Field Thermal Study

The Wateree Station thermal discharge has been examined in the field under all plant operating modes for cooling, including "once-through", "helper" and "closed cycle" cooling modes. River flows during these studies ranged from 1800 cfs to 9740 cfs. Station production averaged 86.9% capacity during the field studies and ranged from 47% to 103% of the rated generating capacity of 720 MWe. A summary of river flows, ambient temperatures, plant production, cooling mode, discharge ΔT and ΔT's approximately 0.5 miles below the discharge is contained in Table 7 for each of the field thermal surveys.

Surface and selected cross section isotherms for the field studies conducted during 1975-77 are noted in Figures 6 to 16. The excess temperatures (ΔT) for each field study, when measured at sample transects number 12-19, are included in Table 8.

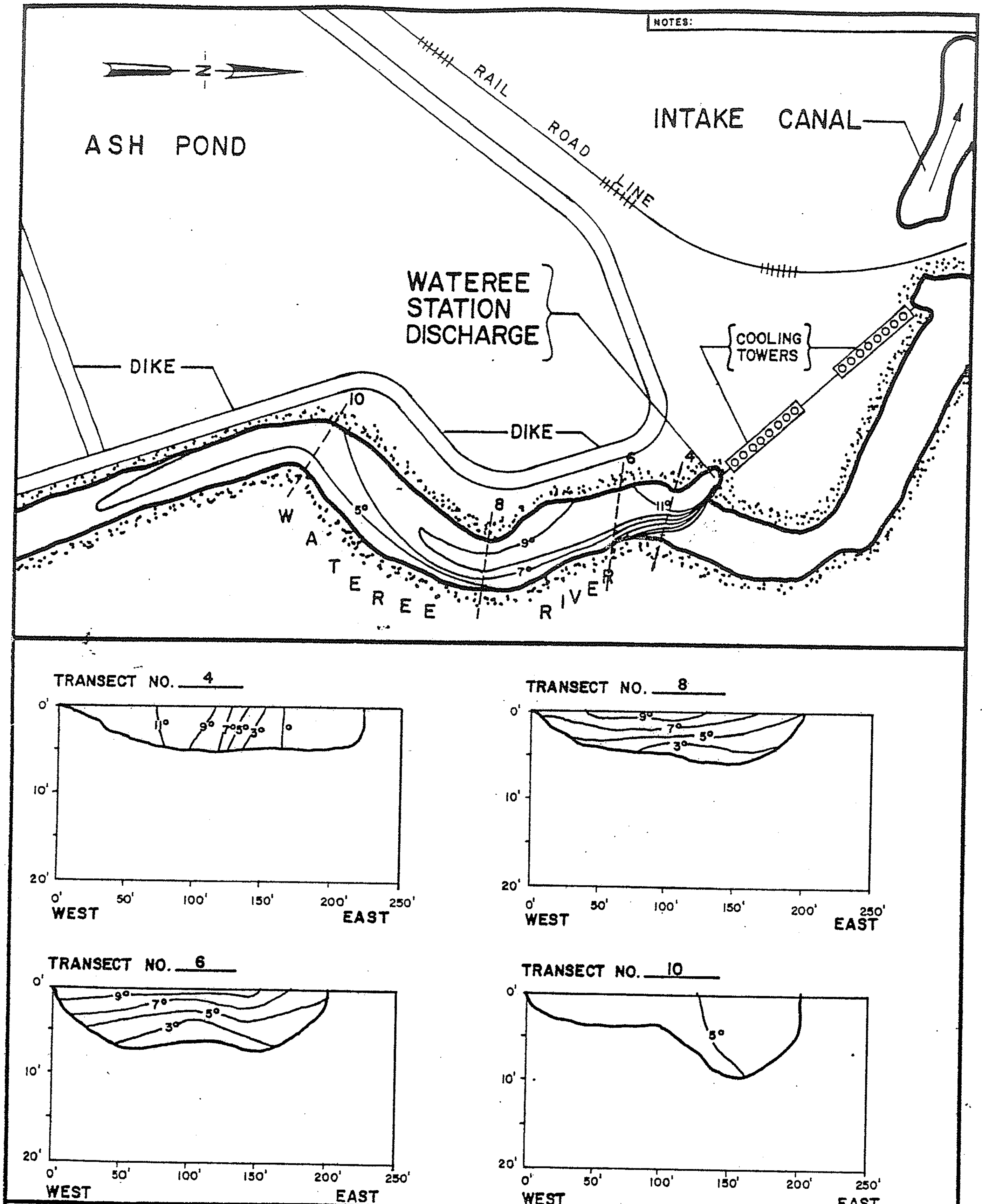
The initial field studies revealed that the river could be divided into two reaches in terms of temperature distributions and primary mode of heat dissipation. The first reach includes the area from the discharge canal to sample transect number 11, approximately 1980 feet below the discharge. Within this reach, "near field" mixing of the heated effluent with ambient water was found to occur. An essentially homogenous temperature distribution was always found at transect number 12. The second reach, in which surface heat transfer is the primary cooling mechanism, begins at transect number 12, and continues downstream approximately 10 miles to the confluence with the Congaree River.

During a river flow of approximately 1800 cfs and with the Station operating in a "once-through" cooling mode, the average excess temperature measured 0.5 miles below the discharge was 4.8°C.

Table 7. Wateree Station field thermal studies data summary.

River Flow a/ (cfs)	Date	Ambient Temp. (°C)	Station Production (% Max)	Cooling Mode (open, helper, closed cycle)	Discharge ΔT (°C)	Average ΔT 0.5 Miles Below Discharge (°C)
9740	12-9-76	8.6	97.0	Open	8.3	1.0
8760	4-2-76	15.2	47.0	Open	5.9	0.7
8310	1-28-76	7.7	72.0	Open	9.6	0.9
6880	6-8-76	23.7	103.0	Open	7.9	1.3
6450	2-18-76	11.6	91.0	Open	10.5	1.7
3600	2-20-77	6.7	68.0	Closed Cycle	13.0	0.7
3040	9-9-75	27.7	98.0	Helper	7.5	1.5
2710	9-8-75(2)	28.7	98.0	Helper	6.6	1.9
2710	9-8-75(1)	28.2	98.0	Open	11.7	3.1
2450	9-2-76	24.7	85.0	Helper	6.5	2.0
1800	8-2-76	28.7	99.0	Open	11.9	4.8

a/ Flows estimated from USGS Gage and rating curve.



DATE AUGUST 2, 1976
AVERAGE MWe PRODUCTION 694 MWe
% MAXIMUM PRODUCTION 96.0 %
COOLING MODE ONCE THROUGH
AVERAGE DISCHARGE ΔT 11.9 °C
AVERAGE AMBIENT TEMPERATURE 29.3 °C
WATEREE RIVER FLOW 1800 cfs

FIGURE 6

EXCESS TEMPERATURE ISOTHERMS (°C)

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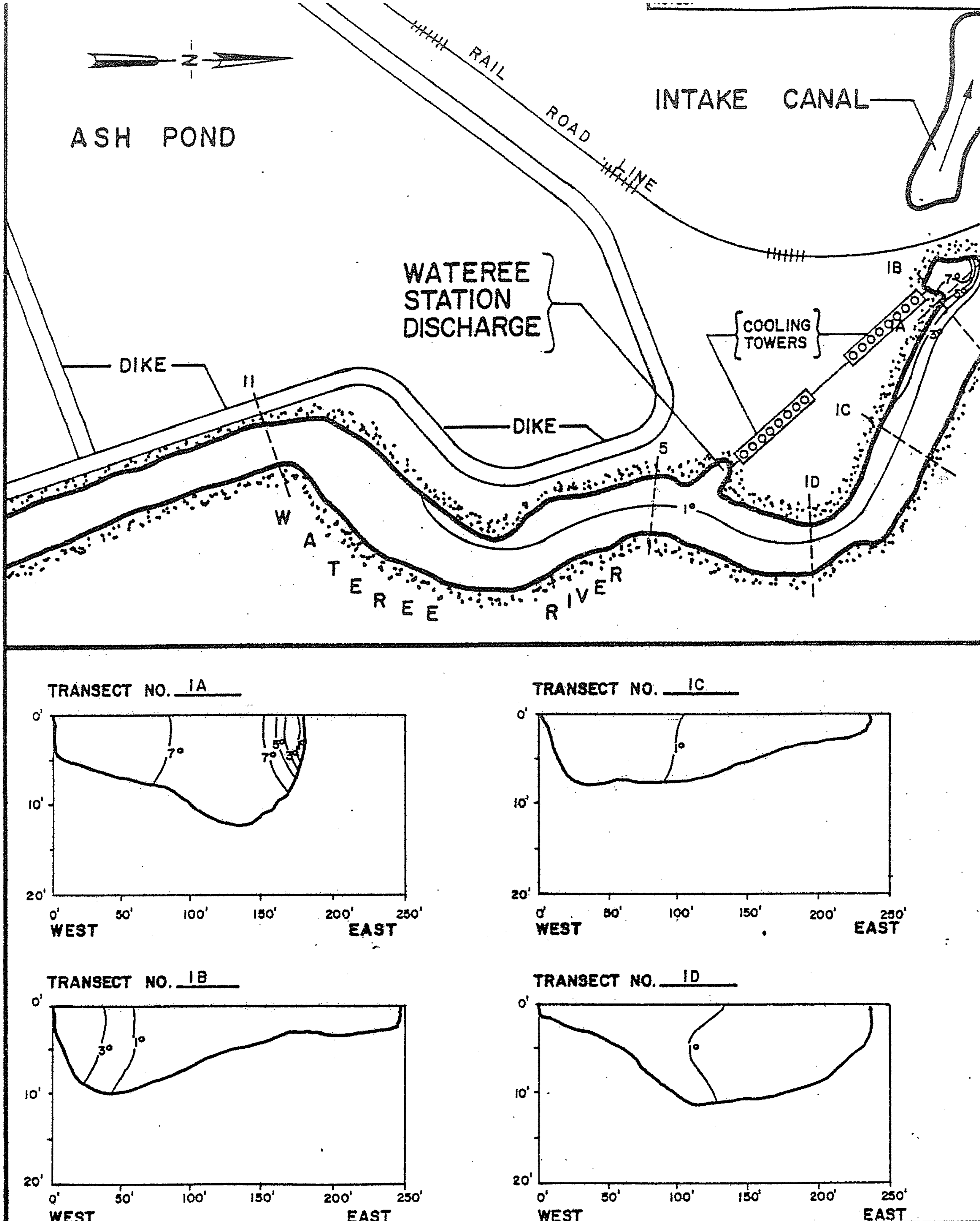

DATE FEBRUARY 20, 1977
AVERAGE MWe PRODUCTION 493 MWe
% MAXIMUM PRODUCTION 68 %
COOLING MODE CLOSED CYCLE
AVERAGE DISCHARGE ΔT 13.0 °C
AVERAGE AMBIENT TEMPERATURE 6.7 °C
WATEREE RIVER FLOW 3600 cfs

FIGURE 7

EXCESS TEMPERATURE ISOTHERMS (°C)

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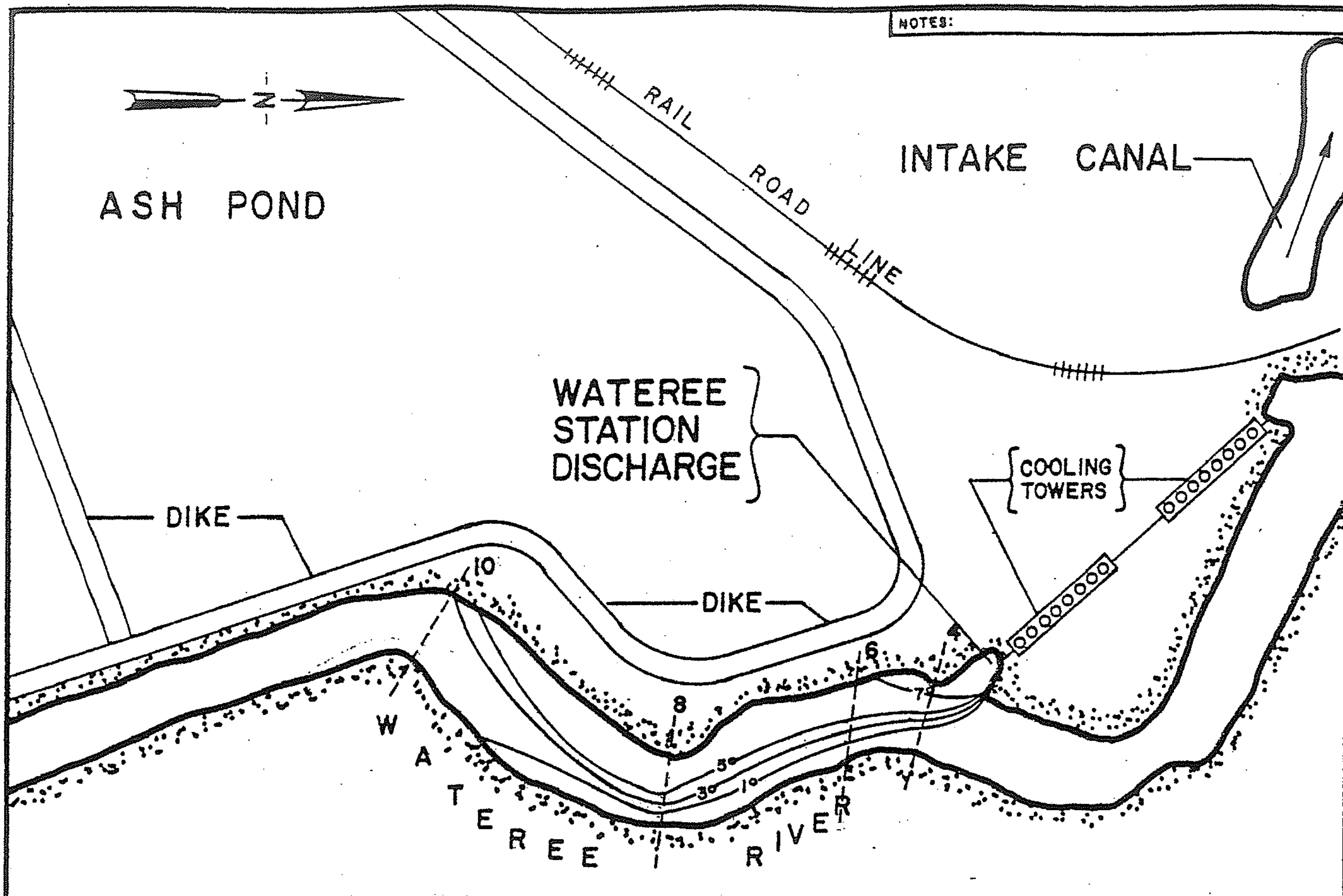

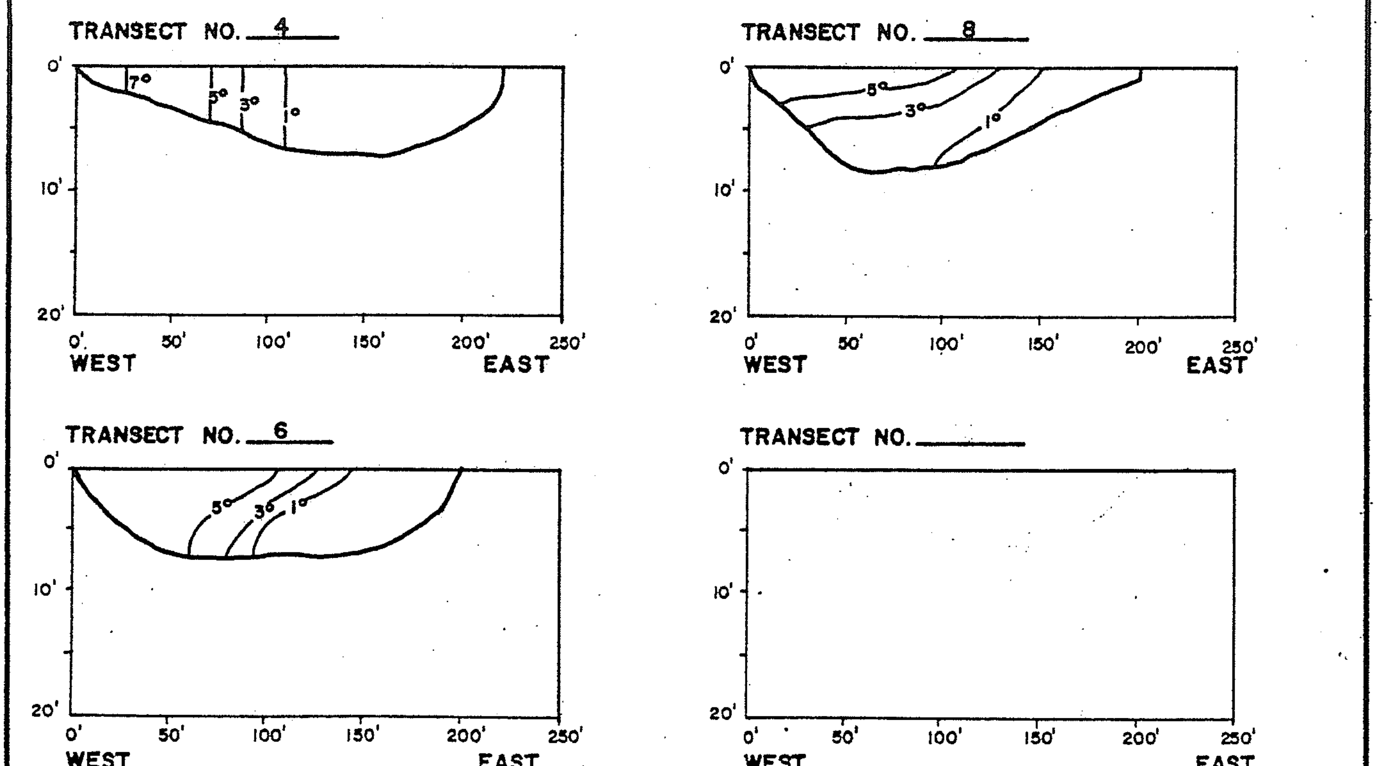

DATE SEPTEMBER, 2 1976

AVERAGE MWe PRODUCTION 611 MWe

% MAXIMUM PRODUCTION 85.0 %

COOLING MODE HELPER

AVERAGE DISCHARGE ΔT 6.5 °C

AVERAGE AMBIENT TEMPERATURE 24.7 °C

WATEREE RIVER FLOW 2450 cfs

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FIGURE 8

EXCESS TEMPERATURE ISOTHERMS (°C)

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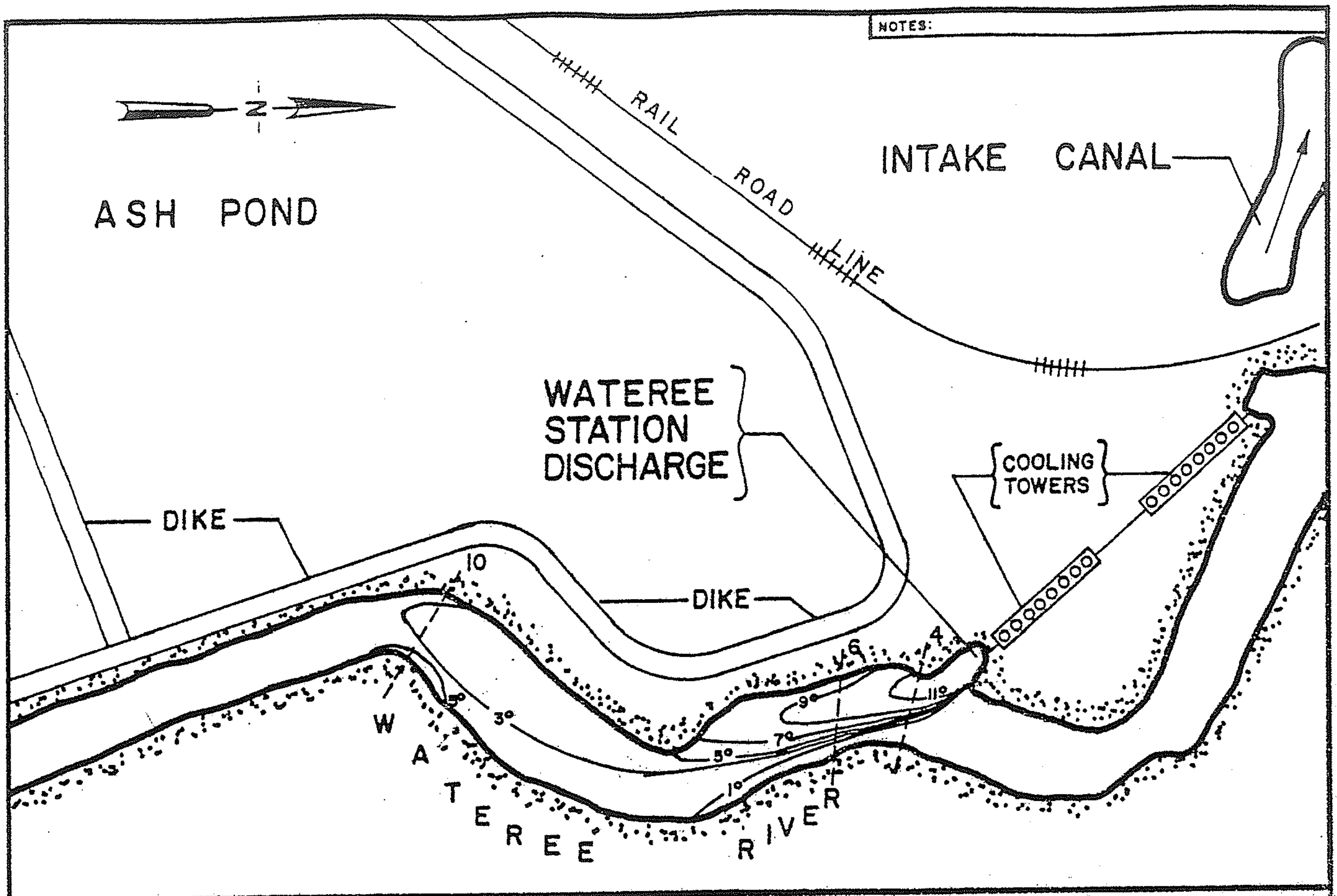

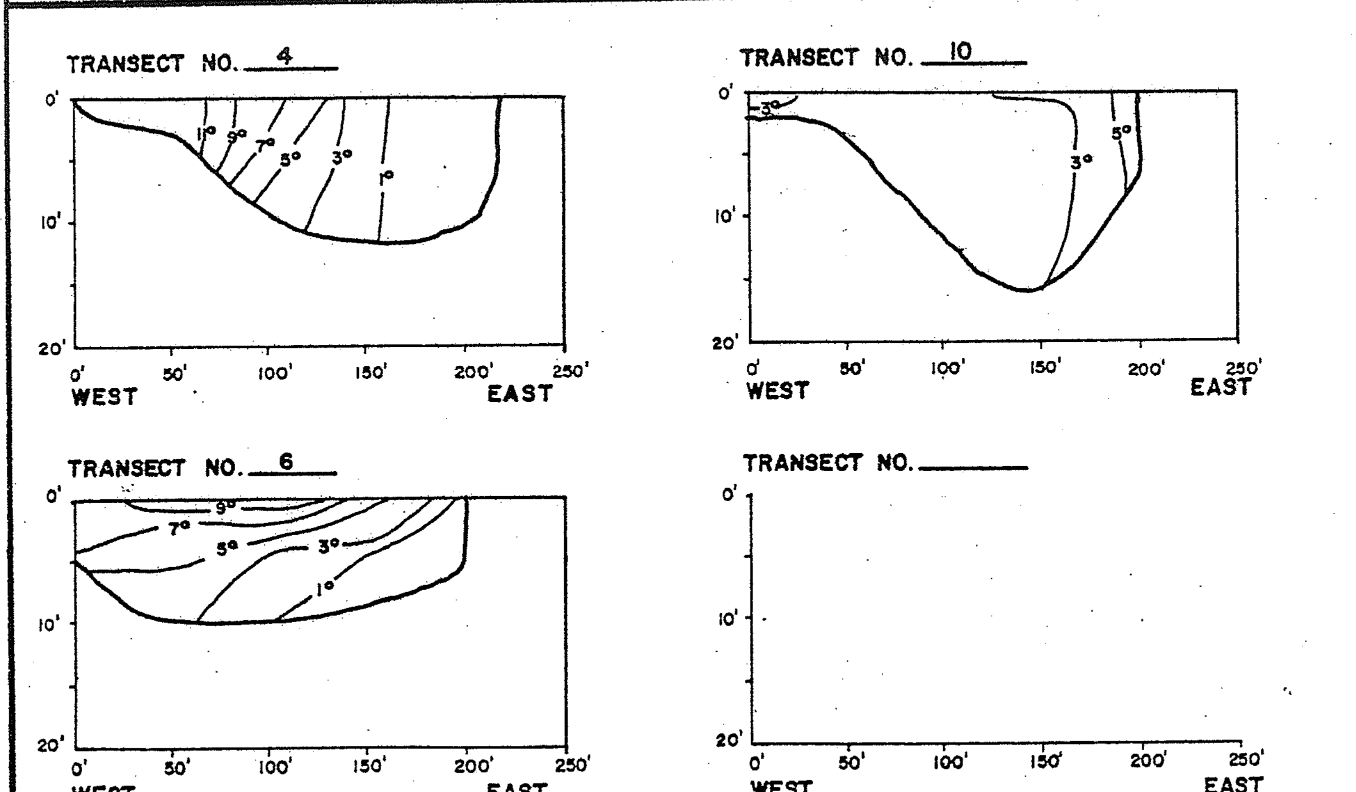

DATE SEPTEMBER 8, 1975
AVERAGE MWe PRODUCTION 709 MWe
% MAXIMUM PRODUCTION 98.0 %
COOLING MODE ONCE THROUGH
AVERAGE DISCHARGE ΔT 11.7 °C
AVERAGE AMBIENT TEMPERATURE 28.2 °C
WATEREE RIVER FLOW 2710 cfs

FIGURE 9

EXCESS TEMPERATURE ISOTHERMS (°C)

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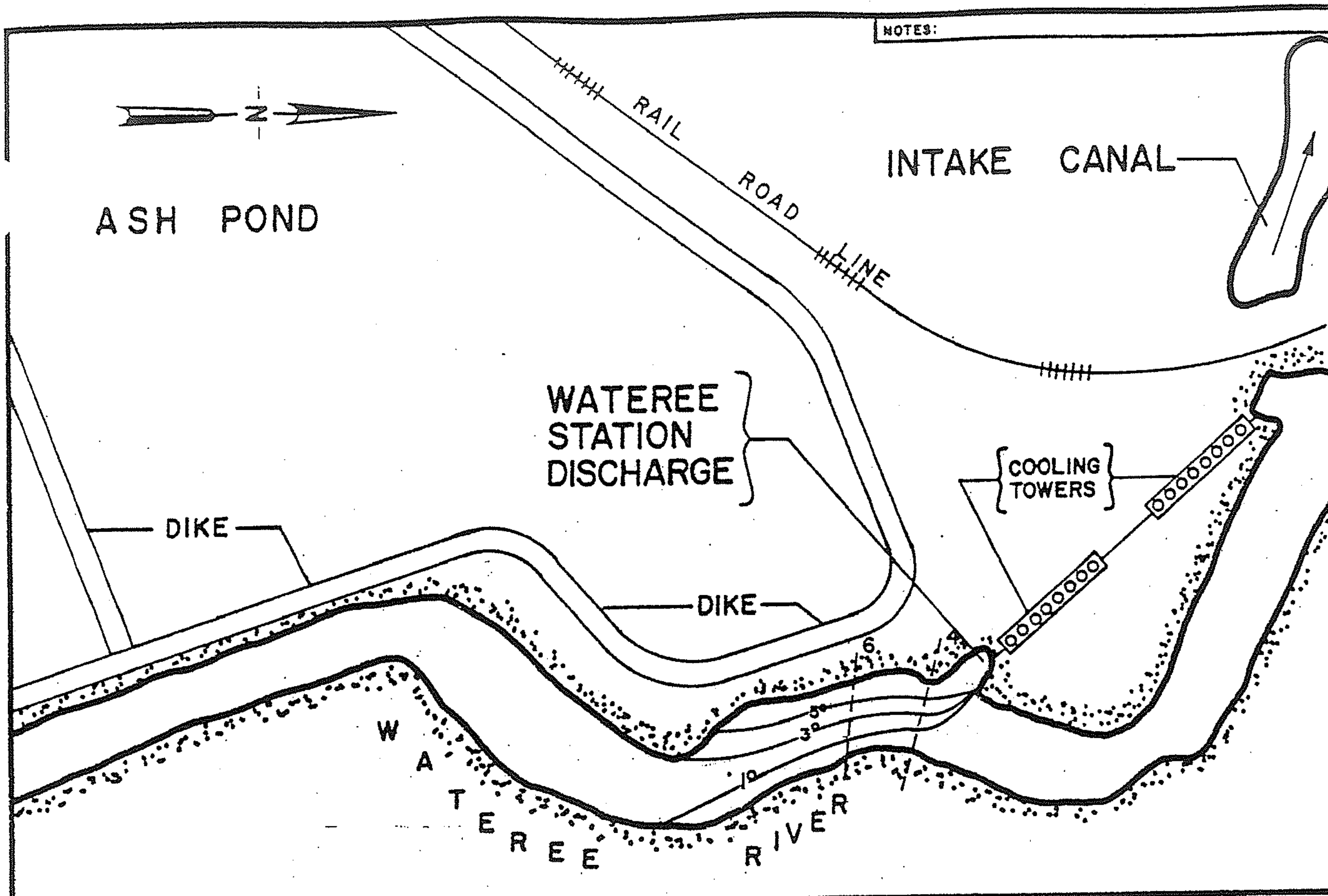

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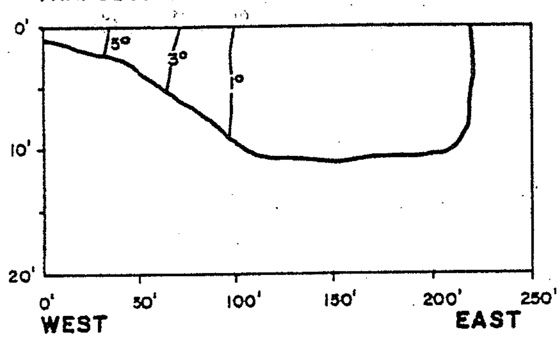

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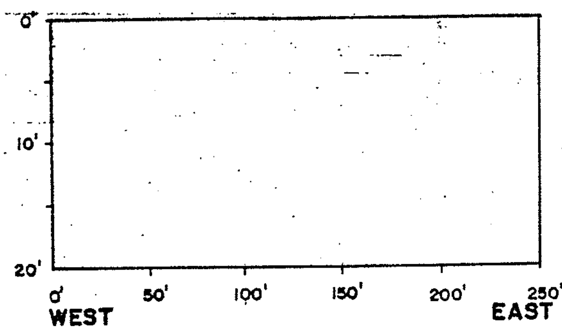

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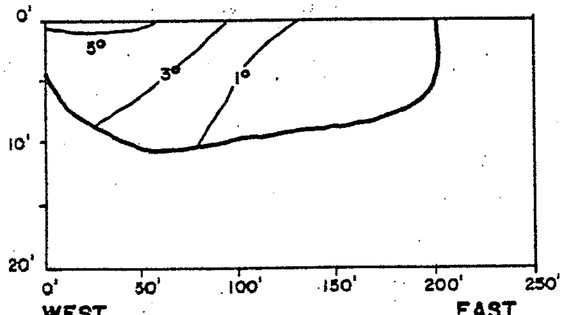

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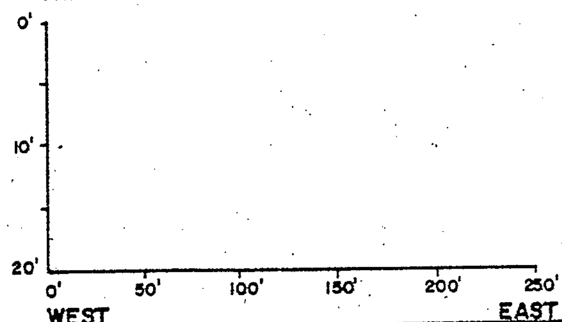

DATE SEPTEMBER 8, 1975

AVERAGE MWe PRODUCTION 709 MWe

% MAXIMUM PRODUCTION 98.0 %

COOLING MODE HELPER

AVERAGE DISCHARGE ΔT 6.6 °C

AVERAGE AMBIENT TEMPERATURE 28.7 °C

WATEREE RIVER FLOW 2710 cfs

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FIGURE 10

EXCESS TEMPERATURE ISOTHERMS (°C)

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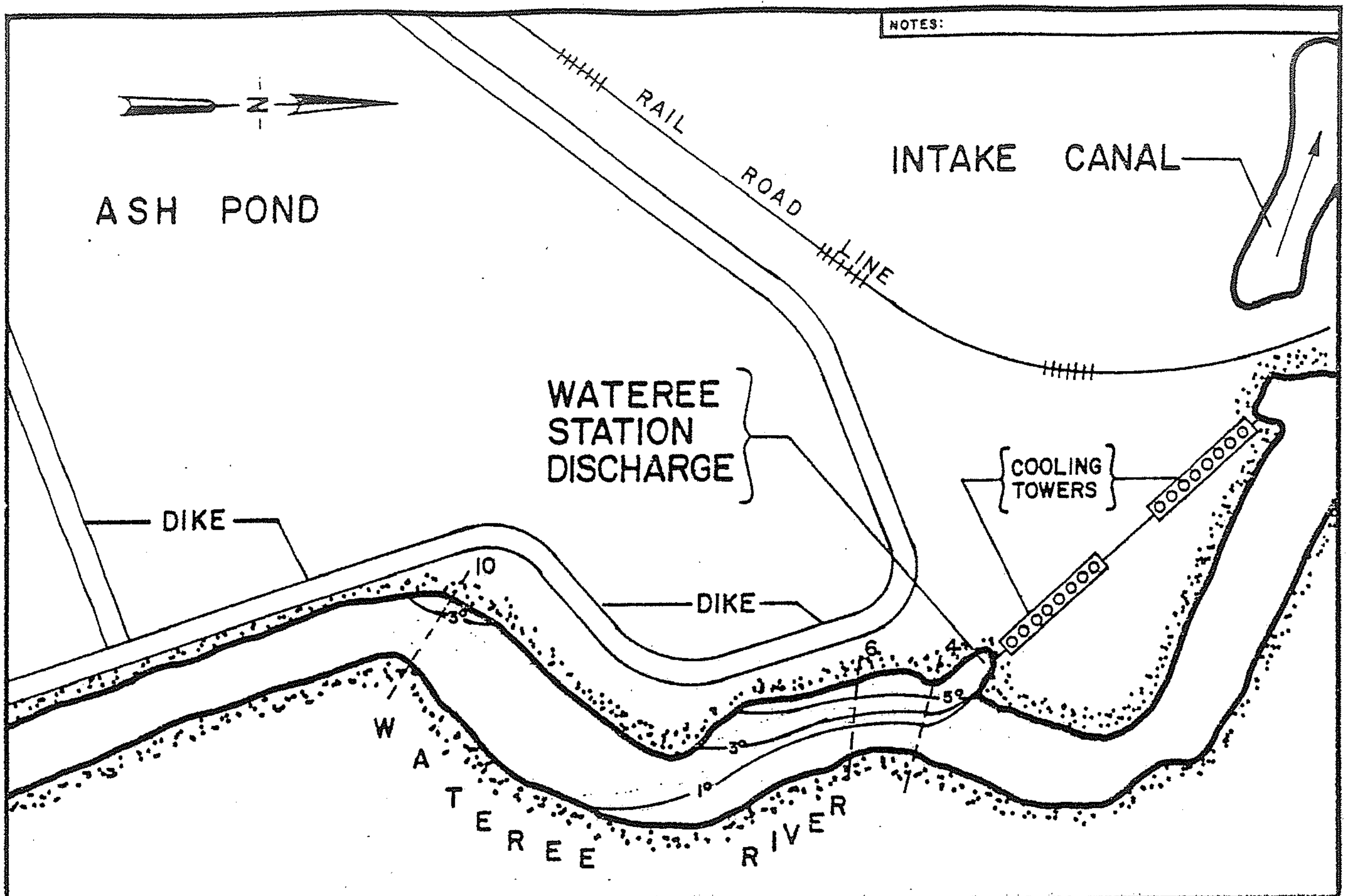

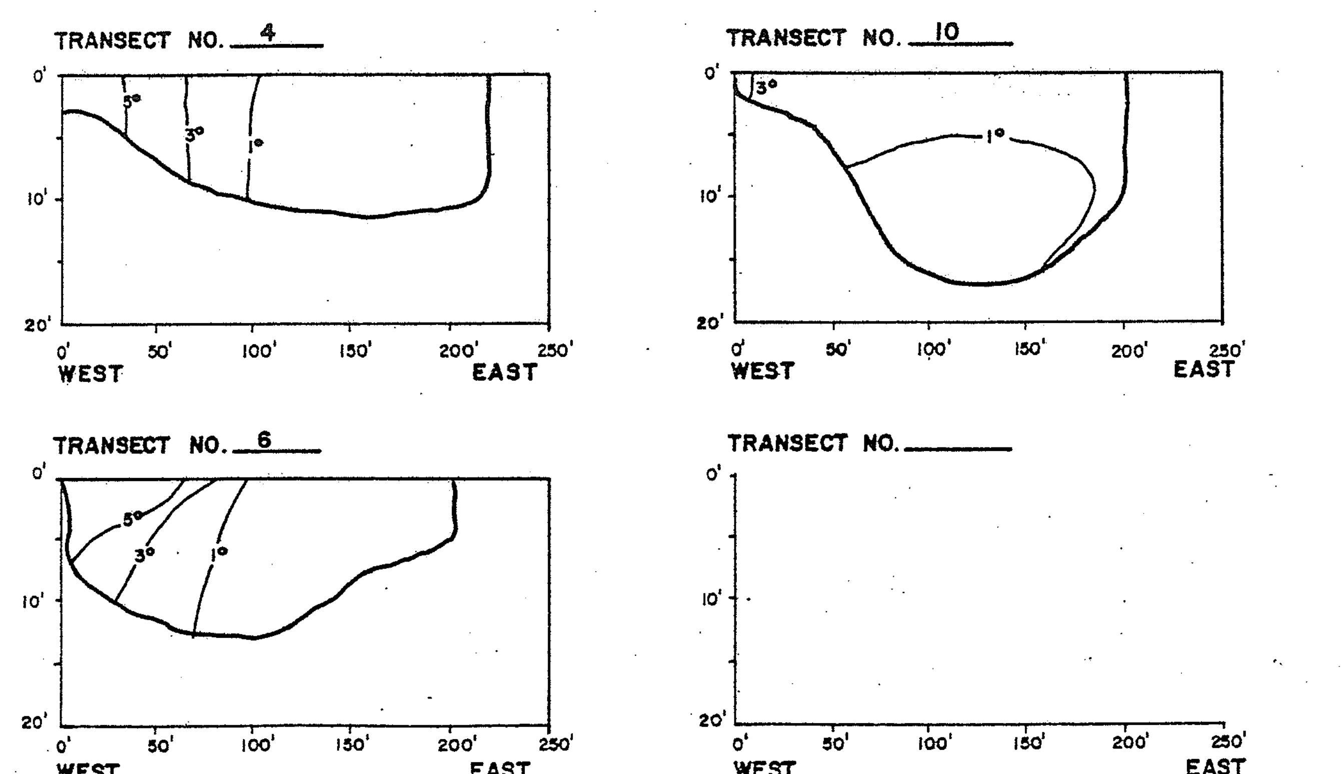

DATE SEPTEMBER 9, 1975
AVERAGE MWe PRODUCTION 709 MWe
% MAXIMUM PRODUCTION 98.0 %
COOLING MODE HELPER
AVERAGE DISCHARGE ΔT 7.5 °C
AVERAGE AMBIENT TEMPERATURE 27.7 °C
WATEREE RIVER FLOW 3040 cfs

FIGURE 11

EXCESS TEMPERATURE ISOTHERMS (°C)

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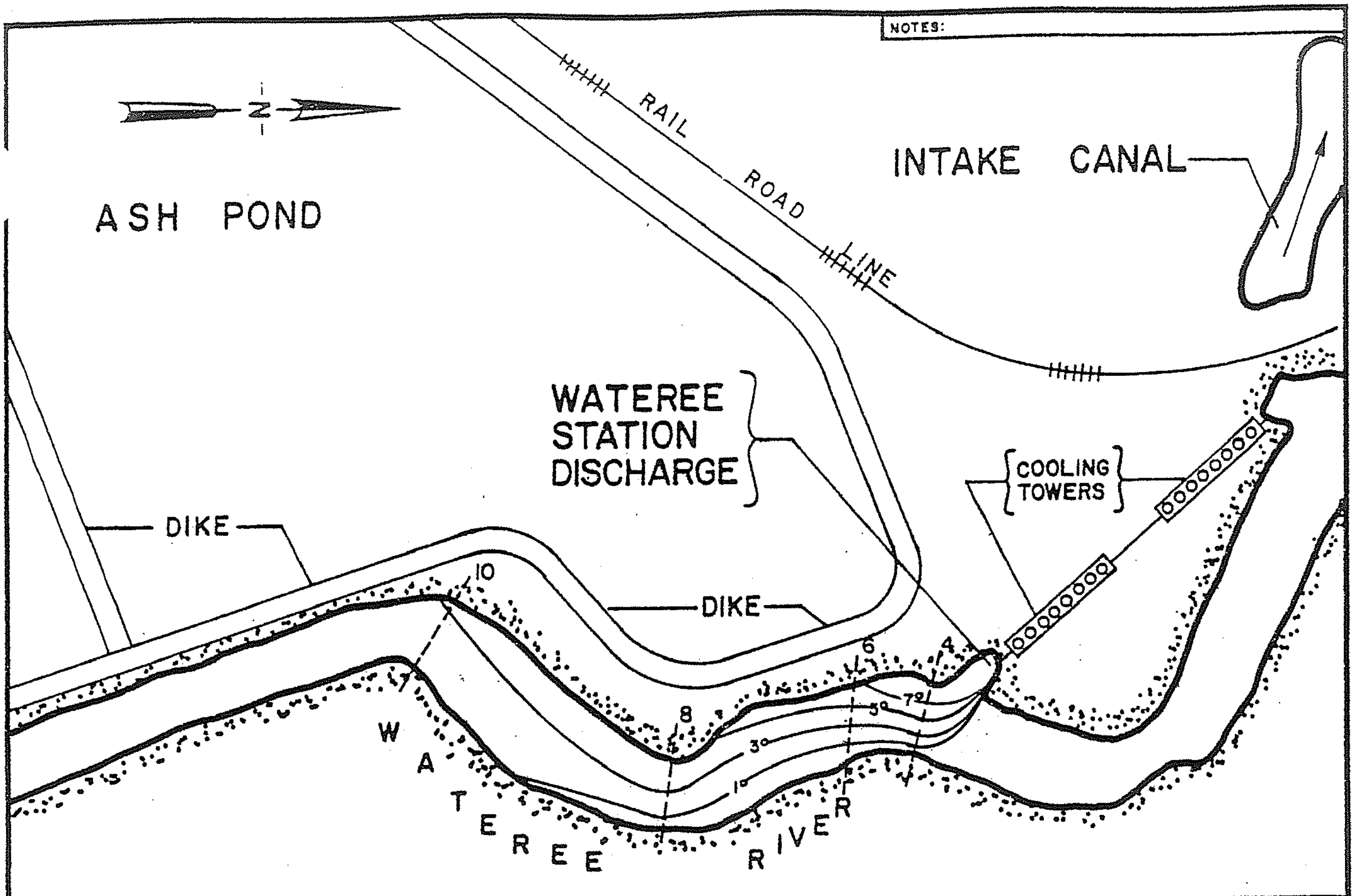

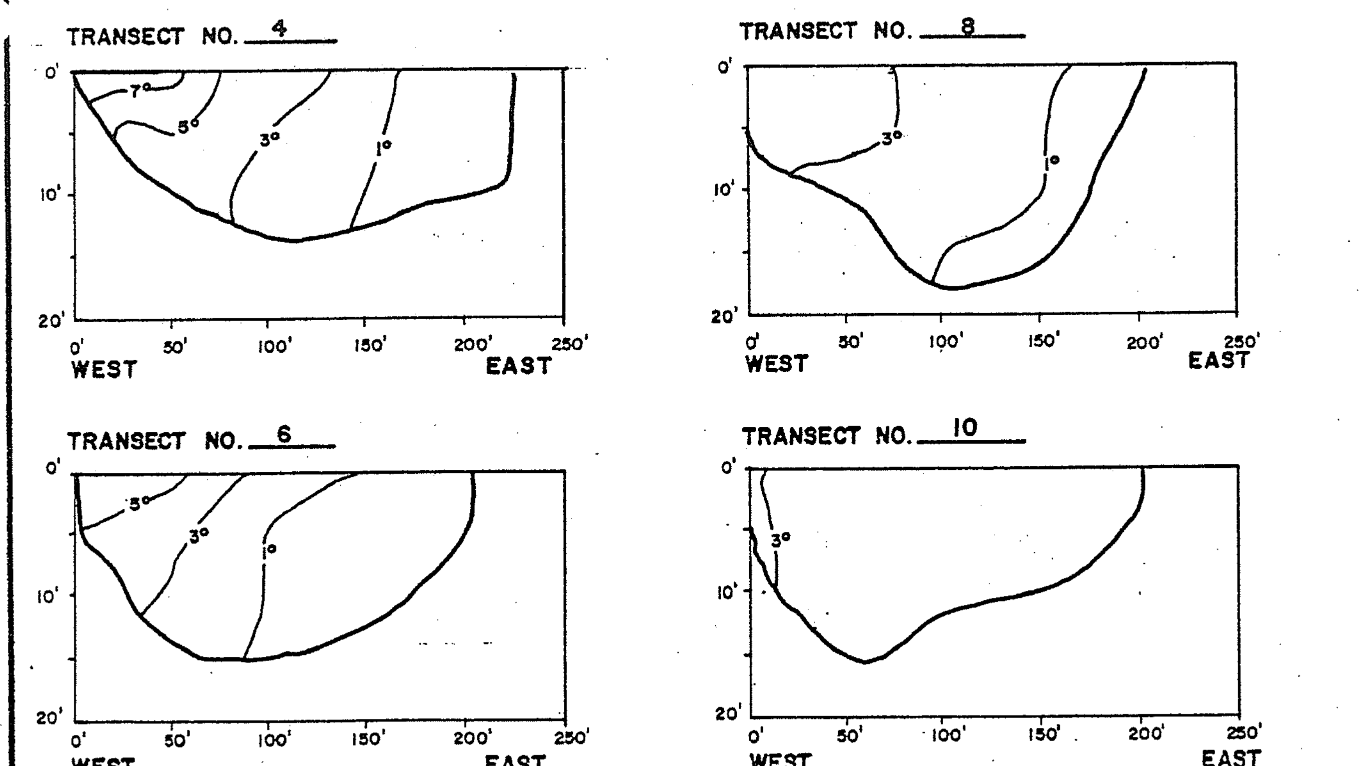

DATE FEBRUARY 18, 1976
AVERAGE MWe PRODUCTION 649 MWe
% MAXIMUM PRODUCTION 90.0 %
COOLING MODE ONCE THROUGH
AVERAGE DISCHARGE ΔT 10.5 °C
AVERAGE AMBIENT TEMPERATURE 11.6 °C
WATEREE RIVER FLOW 6450 cfs

FIGURE 12

EXCESS TEMPERATURE ISOTHERMS (°C)

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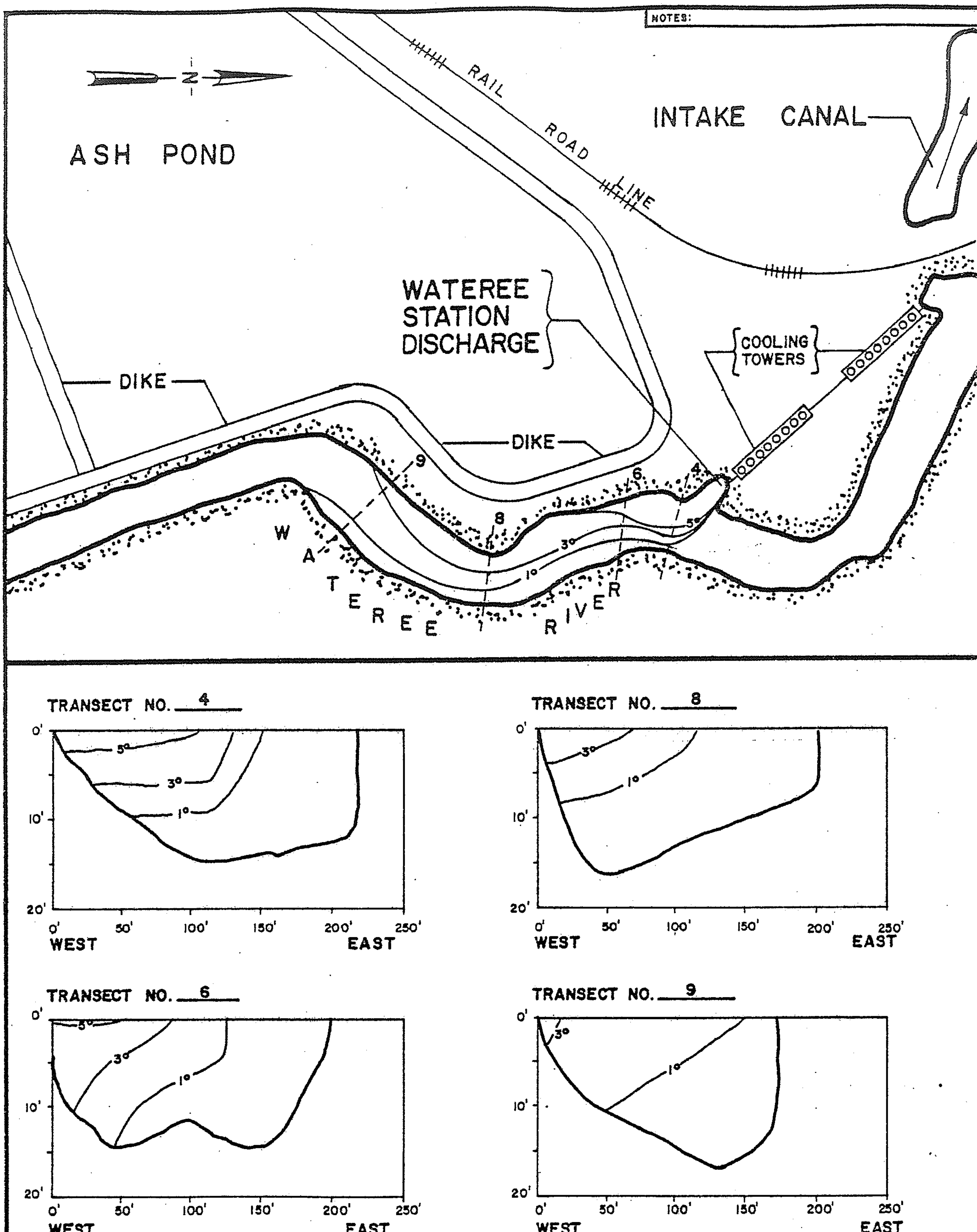

DATE JUNE 8, 1976

AVERAGE MWe PRODUCTION 731 MWe

% MAXIMUM PRODUCTION 102.0 %

COOLING MODE ONCE THROUGH

AVERAGE DISCHARGE ΔT 7.9 °C

AVERAGE AMBIENT TEMPERATURE 23.7 °C

WATEREE RIVER FLOW 6880 cfs

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FIGURE 13

EXCESS TEMPERATURE ISOTHERMS (°C)

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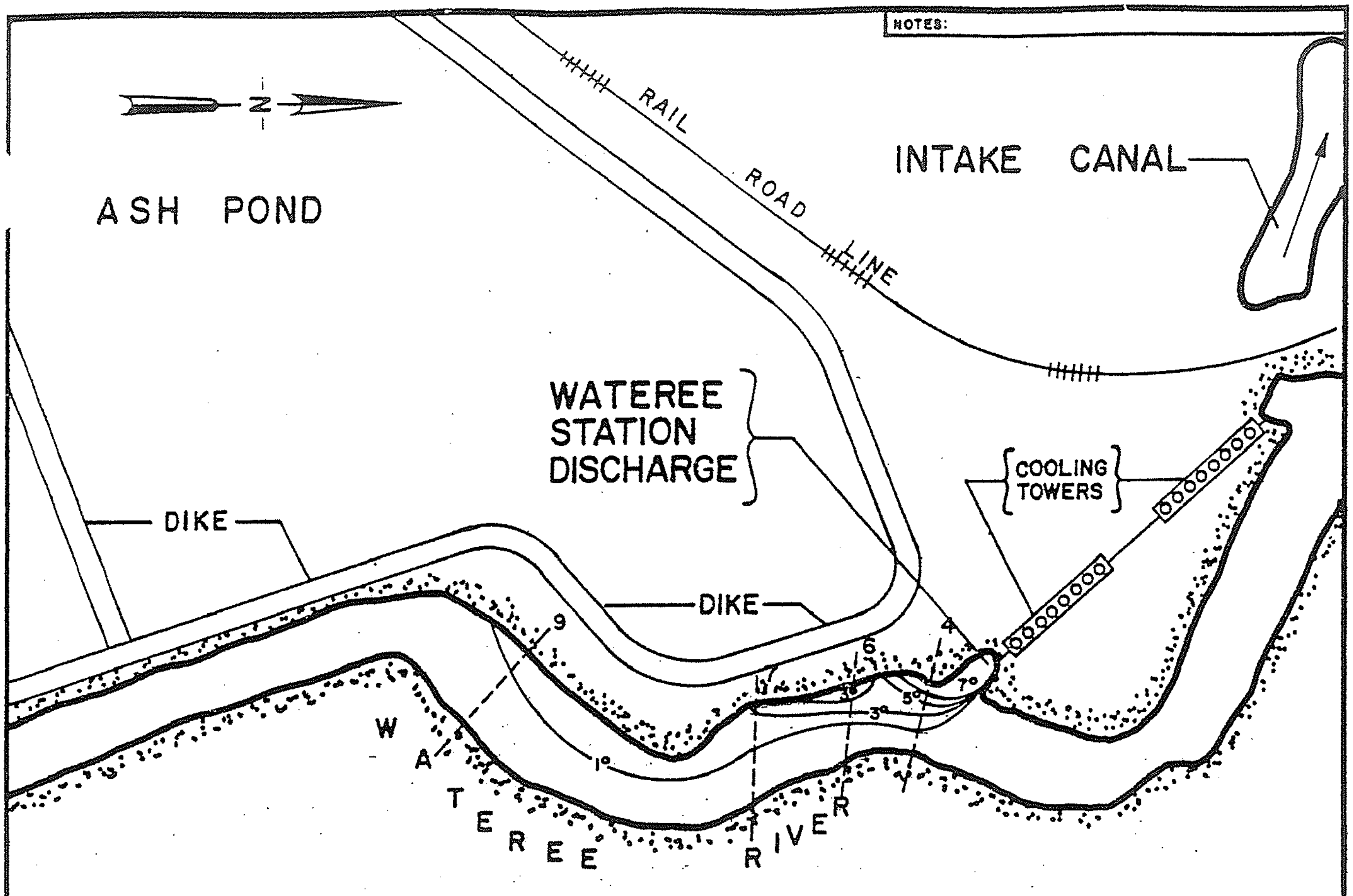

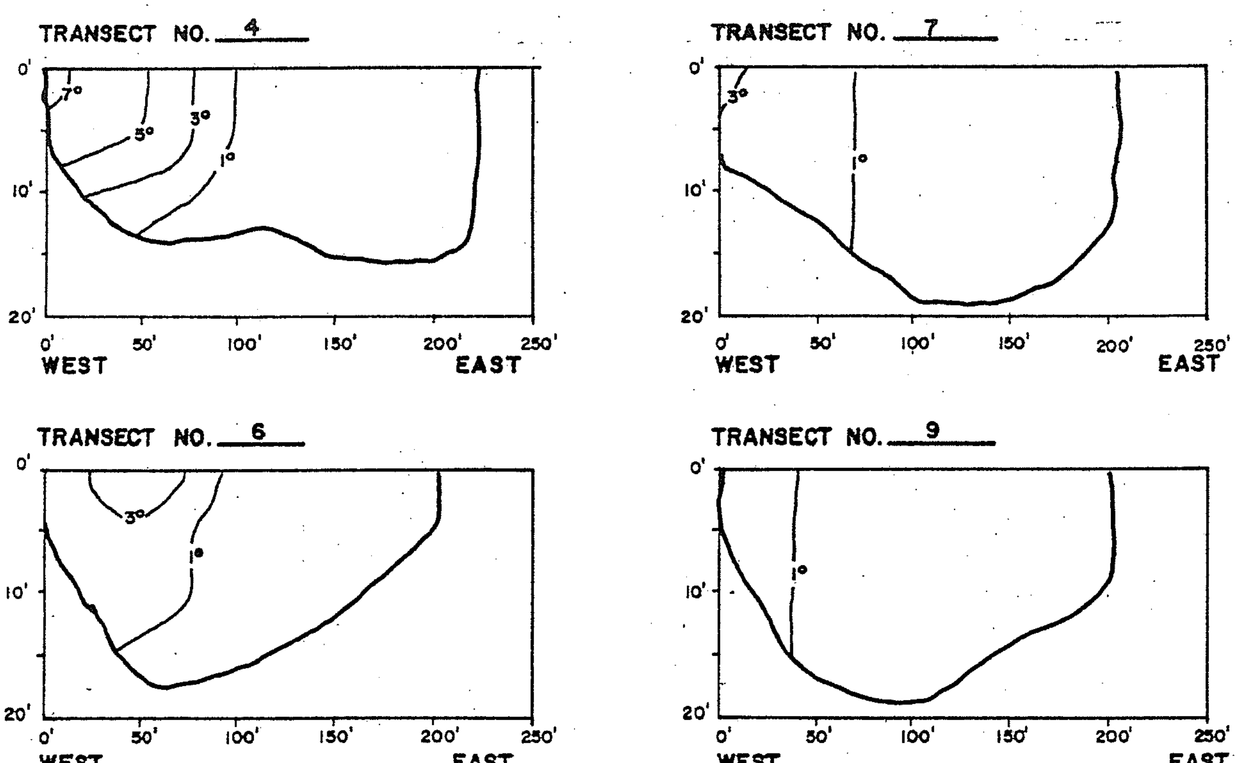

DATE JANUARY 28, 1976
AVERAGE MWe PRODUCTION 521 MWe
% MAXIMUM PRODUCTION 72.0 %
COOLING MODE ONCE THROUGH
AVERAGE DISCHARGE ΔT 9.6 °C
AVERAGE AMBIENT TEMPERATURE 7.7 °C
WATEREE RIVER FLOW 8310 cfs

FIGURE 14

EXCESS TEMPERATURE ISOTHERMS (°C)

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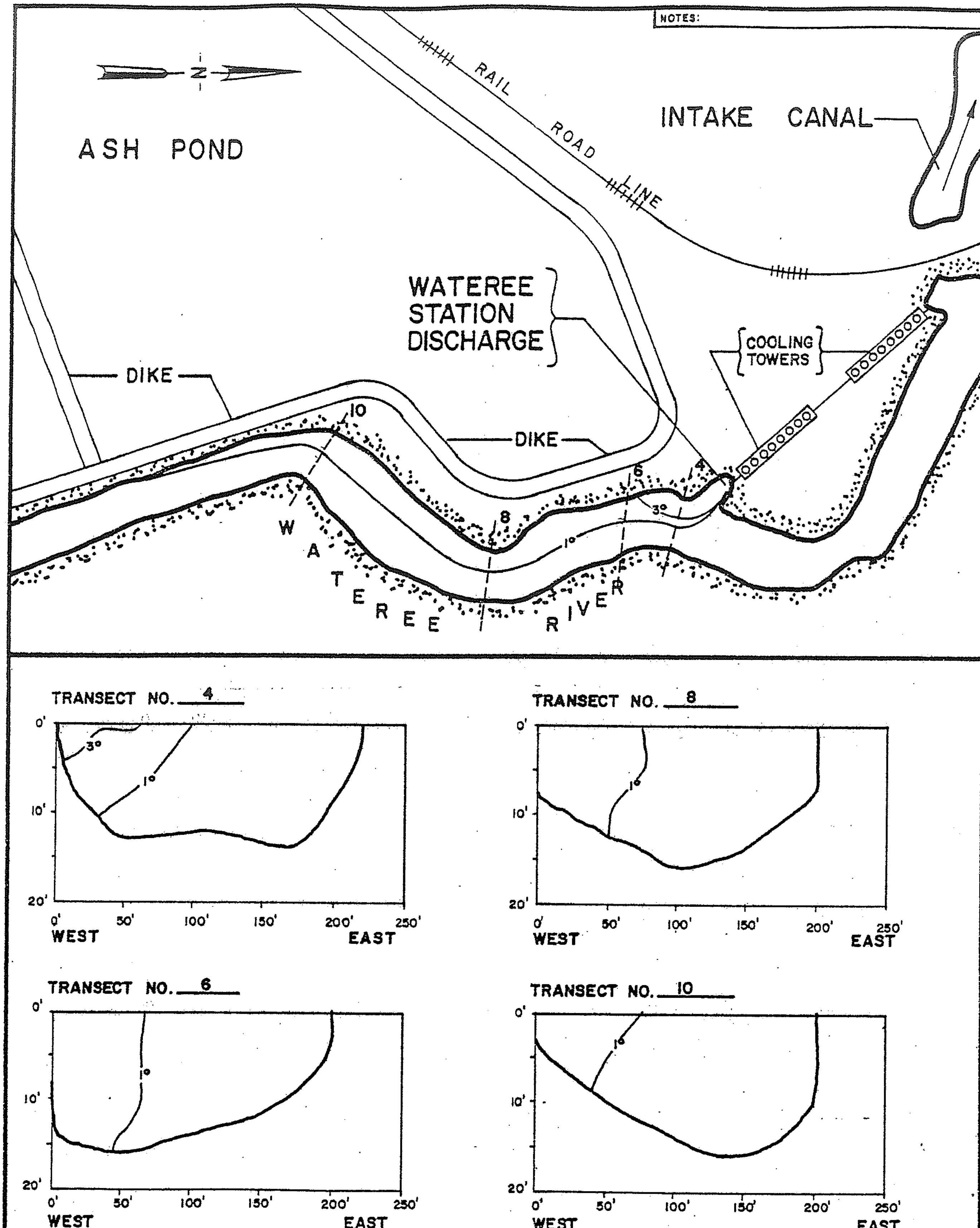

DATE	APRIL 2, 1976
AVERAGE MWe PRODUCTION	340 MWe
% MAXIMUM PRODUCTION	47.0 %
COOLING MODE	ONCE THROUGH
AVERAGE DISCHARGE ΔT	5.9 °C
AVERAGE AMBIENT TEMPERATURE	15.2 °C
WATEREE RIVER FLOW	8760 cfs

FIGURE 15

EXCESS TEMPERATURE ISOTHERMS (°C)

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DATE | SCALE | DWG. NO.

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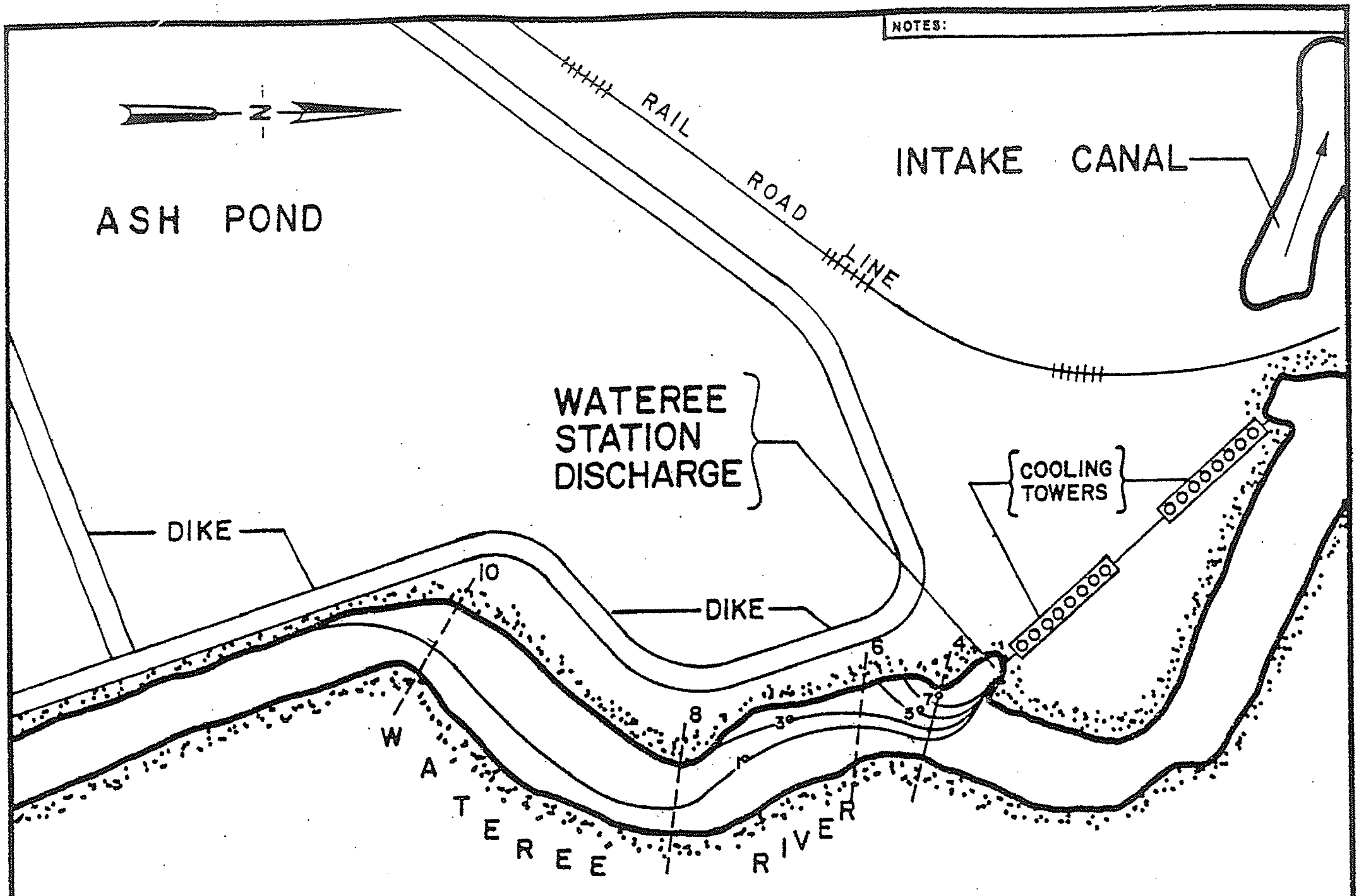

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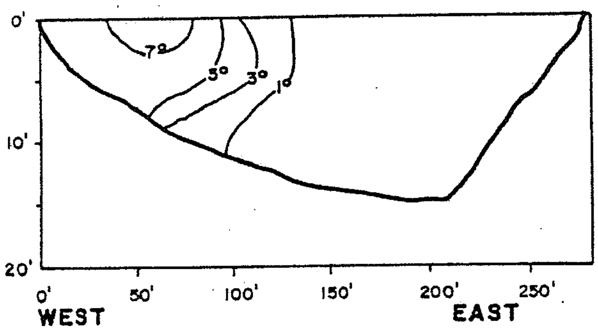

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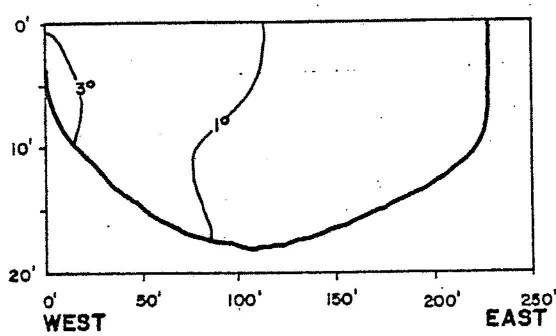

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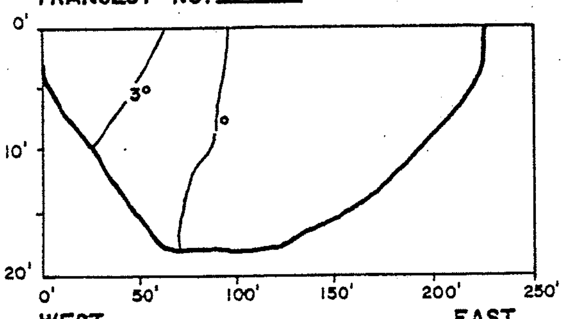

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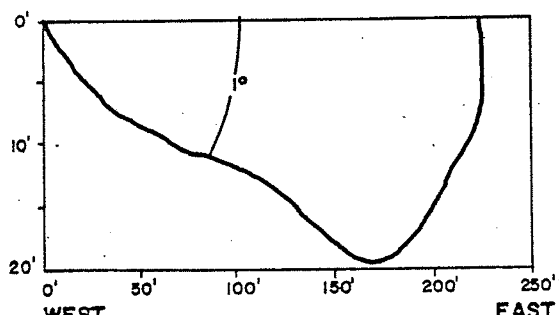

DATE DECEMBER 9, 1976
AVERAGE MWe PRODUCTION 697 MWe
% MAXIMUM PRODUCTION 97.0 %
COOLING MODE ONCE THROUGH
AVERAGE DISCHARGE ΔT 8.3 °C
AVERAGE AMBIENT TEMPERATURE 8.6 °C
WATEREE RIVER FLOW 9740 cfs

FIGURE 16

EXCESS TEMPERATURE ISOTHERMS (°C)

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Table 8. Wateree Station excess temperatures (Δ T, °C) measured below Transect No. 11 during field thermal studies.

Date	Transect #	Distance Below Discharge (Miles)	Average Δ T (°C)	Date	Transect #	Distance Below Discharge (Miles)	Average Δ T (°C)
12-9-76	12	0.5	0.7	4-2-76	12	0.5	0.7
	13	0.8	0.6		13	0.8	0.7
					14	1.0	0.7
9-2-76	12	0.5	2.0		16	3.0	0.7
	13	0.8	2.0				
	14	1.0	2.0	2-18-76	12	0.5	1.7
	15	2.0	2.0		13	0.8	1.7
	16	3.0	2.1		15	2.0	1.6
	17	4.0	2.0		16	3.0	1.6
					17	4.0	1.6
8-2-76	12	0.5	4.8				
	13	0.8	4.7	1-28-76	12	0.5	0.9
	14	1.0	4.5		13	0.8	0.9
	15	2.0	4.7		16	3.0	0.8
	16	3.0	4.7		17	4.0	0.6
	17	4.0	4.5				
	18	4.7	4.4	9-9-75	13	0.8	1.3
	19	10.5	1.7				
				9-8-75	13	0.8	3.0
6-8-76	12	0.5	1.3		15	2.0	2.9
	13	0.8	1.3				
	15	2.0	1.2				
	16	3.0	1.2				
	17	4.0	1.2				
	18	4.7	1.2				
	19	10.5	0.3				

Lightning storm damage prevented cooling tower operation so that no observations could be made on the reduction of stream temperature by the cooling towers.

Flows of less than the 7Q10 flow were recorded by the USGS gaging station near the cooling water intake during three days of September 1976. However, an evaluation of thermal distributions during these low flows was not performed in the field, primarily because the unpredictable variation in daily river flows prevented scheduling field work to coincide with the low flows. Plant operating personnel indicated that, during these three days, September 7, 8, and 14 (flows recorded by USGS of 760 cfs, 796 cfs and 775 cfs, respectively) the cooling towers were operating in a partially closed cycle mode, with the gates on the upper end on the cooling tower basin partially open, such that some recirculation occurred. Temperatures measured 0.8 miles below the discharge were 1.3°C (2.3°F), 2.8°C (5.0°F) and 3.6°C (6.5°F), respectively, above upstream ambient temperatures recorded by USGS near the cooling water intake. These temperatures should be representative of the temperatures at the point of initial mixing, 0.5 miles below the discharge, as the maximum variance in temperature measured between these two points (0.5 and 0.8 miles) during measurement at other river flows was 0.1°C (0.2°F).

The "closed-cycle" cooling mode was evaluated in the field during February 19-20, 1977. The Station was able to generate up to 692 MWe or 96% of its rated capacity. Due to a mechanical problem in the coal supply system, a sustained high production load was not possible and the average production during the 18 hour test period was 493 MWe or 68% of maximum capacity.

During the "closed-cycle" cooling test, the temperature rise across both unit condensers averaged 10.7°C (19.2°F). The temperature drop across the Station cooling towers was 2.8°C (5.0°F), and an additional temperature drop of 4.8°C (8.6°F) was measured from the east edge of the intake canal to the face of the intake screens. It appeared that the majority of cooling occurred between the cooling towers and the intake screens. The cooling tower performance is attributed to low ambient air temperature of 9.4°C (48.9°F). Mixing of ambient river water in the intake canal and subsequent overflow of heated effluent into the river is believed to account for the temperature drop from the towers to the intake. The extent of the mixing in the river is noted in Figure 7 which describes plan and cross section views of excess temperatures in the Wateree River under "closed-cycle" cooling.

Figure 7 indicates that the mixing of heated effluent from the intake canal during "closed-cycle" operation had little impact on the river. At lower river flows, the ambient water velocity is lowered and the velocity through the six conduit pipes leading to the intake canal should be greater compared to the river velocity. This increased velocity in the conduits leading to the intake canal at low river water flows should serve to reduce the mixing of the heated effluent with ambient river water. Additionally, more favorable meteorological conditions are expected during low flow periods, and cooling tower performance should appreciably increase. It therefore appears that for low flow periods, the "closed-cycle" operating mode is feasible and will have little impact on ambient temperatures in the Wateree River.

Field thermal data collected at river flows of 2450 to 3040 cfs indicate that with cooling towers operating in the "helper" mode, the ΔT 0.5 miles downstream was 1.5-2.0°C (2.7-3.6°F) (Figures 8, 10 and 11). Without cooling towers, and a river flow of 2710 cfs, the ΔT 0.5 miles downstream was 3.1°C (Figure 9).

Field thermal measurements made during "once-through" cooling operation at river flows from 6450 cfs to 9740 cfs showed a ΔT 0.5 miles downstream of 1.7-0.7°C (3.1-1.3°F) (Figures 12, 13, 14, 15 and 16).

b. Mathematical Model

Prediction of flows and resultant temperatures at the point of initial mixing, 0.5 miles downstream, were made using the six design criteria described earlier and are shown in Figures 17 through 20. The design conditions used are hypothetical and are a combination of very conservative conditions which is most unlikely to occur. Plant operating modes for maintenance of a mixed temperature of 34.0°C (94.2°F) or less are noted in these figures. Maintenance of this temperature under these extreme design conditions will allow short term survival for the primary sport species (channel catfish, largemouth bass, bluegill) collected during the study. Near and far field predictions of thermal

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WATEREE STATION

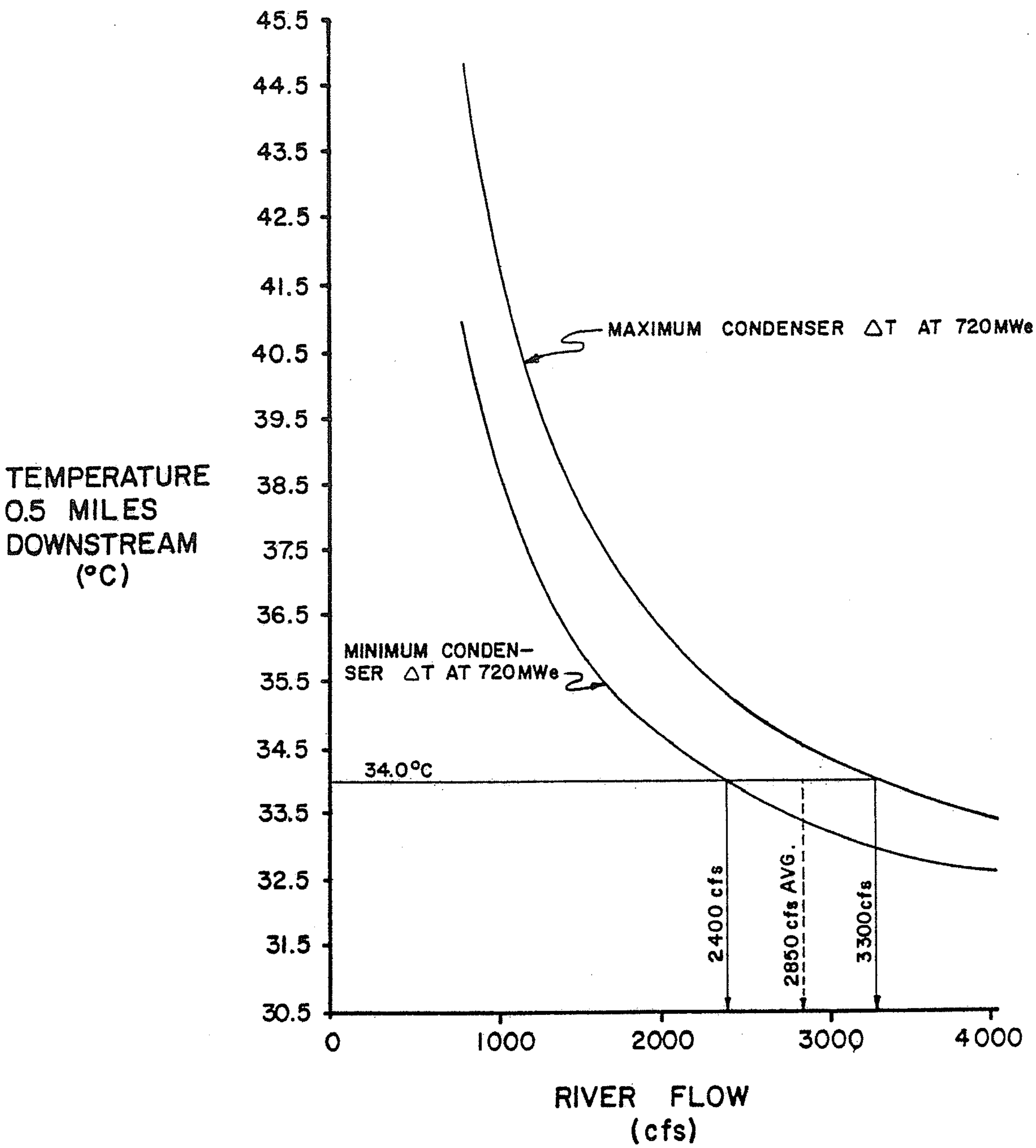

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FIGURE 17

TEMPERATURE (°C) RANGE PREDICTED 0.5 Mi. DOWNSTREAM WITH ONCE THROUGH COOLING AT MAXIMUM STATION PRODUCTION.

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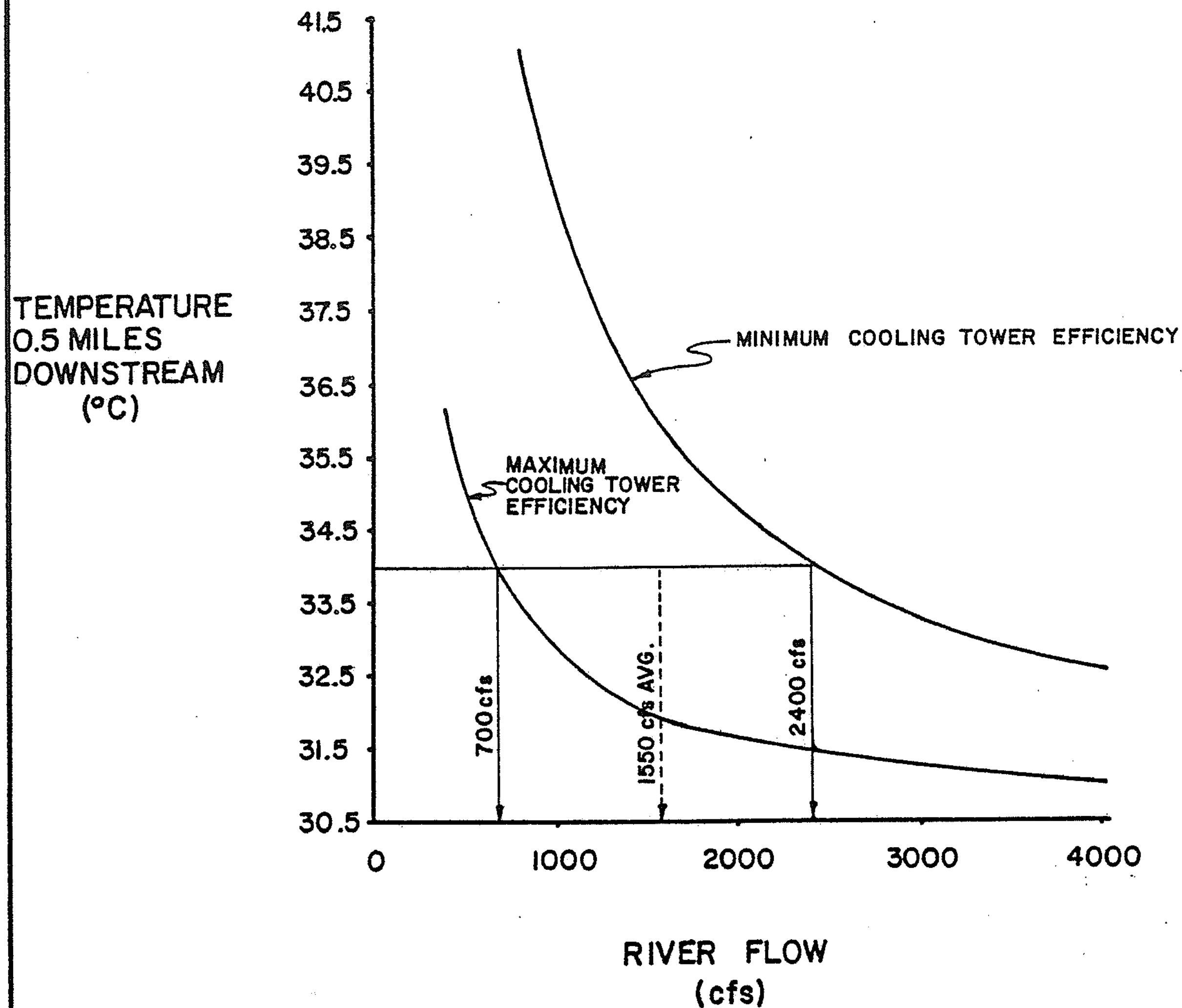

FIGURE 18

PREDICTED TEMPERATURE (°C) RANGE 0.5 MILES DOWNSTREAM WITH COOLING TOWER OPERATION AT MAXIMUM STATION PRODUCTION.

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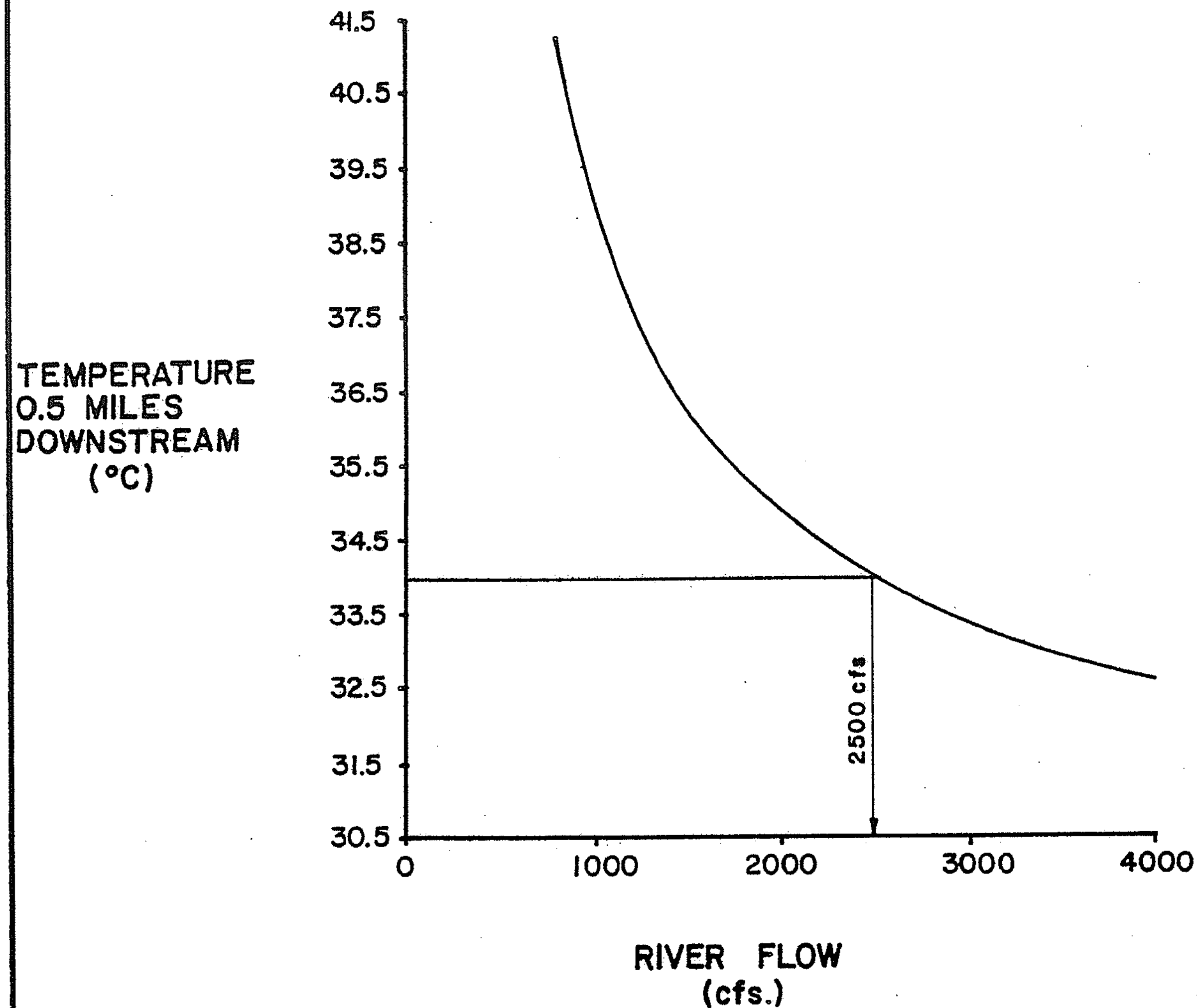

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FIGURE 19

TEMPERATURE PREDICTED 0.5 MILES DOWN-STREAM WITH ONCE THROUGH COOLING AND AVERAGE STATION PRODUCTION OF 65.5% (472)MWe.

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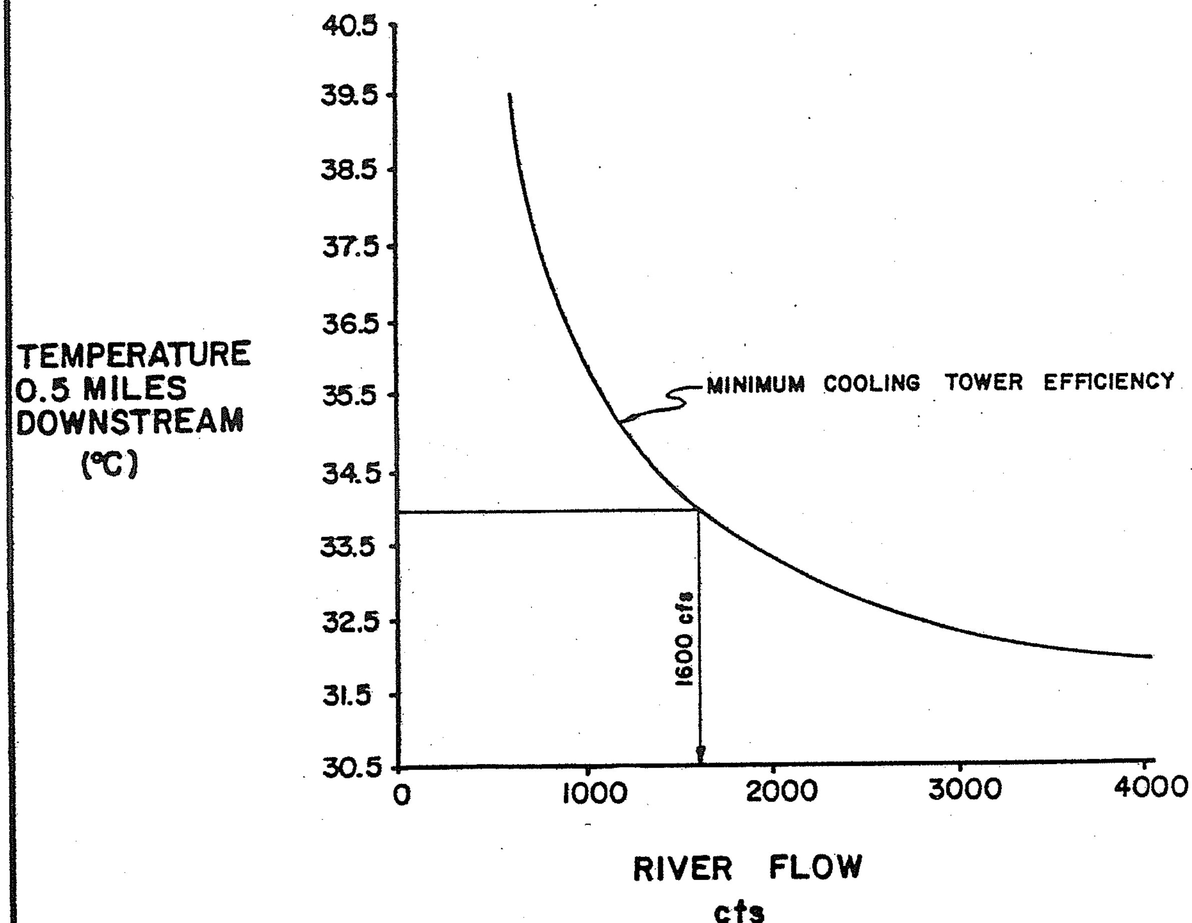
NOTES:

WATEREE STATION



REV.	DATE	BY	DESCRIPTION	APP.

REVISION

FIGURE 20

TEMPERATURE PREDICTED 0.5 MILES DOWNSTREAM WITH COOLING TOWERS OPERATING AND AVERAGE STATION PRODUCTION OF 65.5 % (472 MWe)

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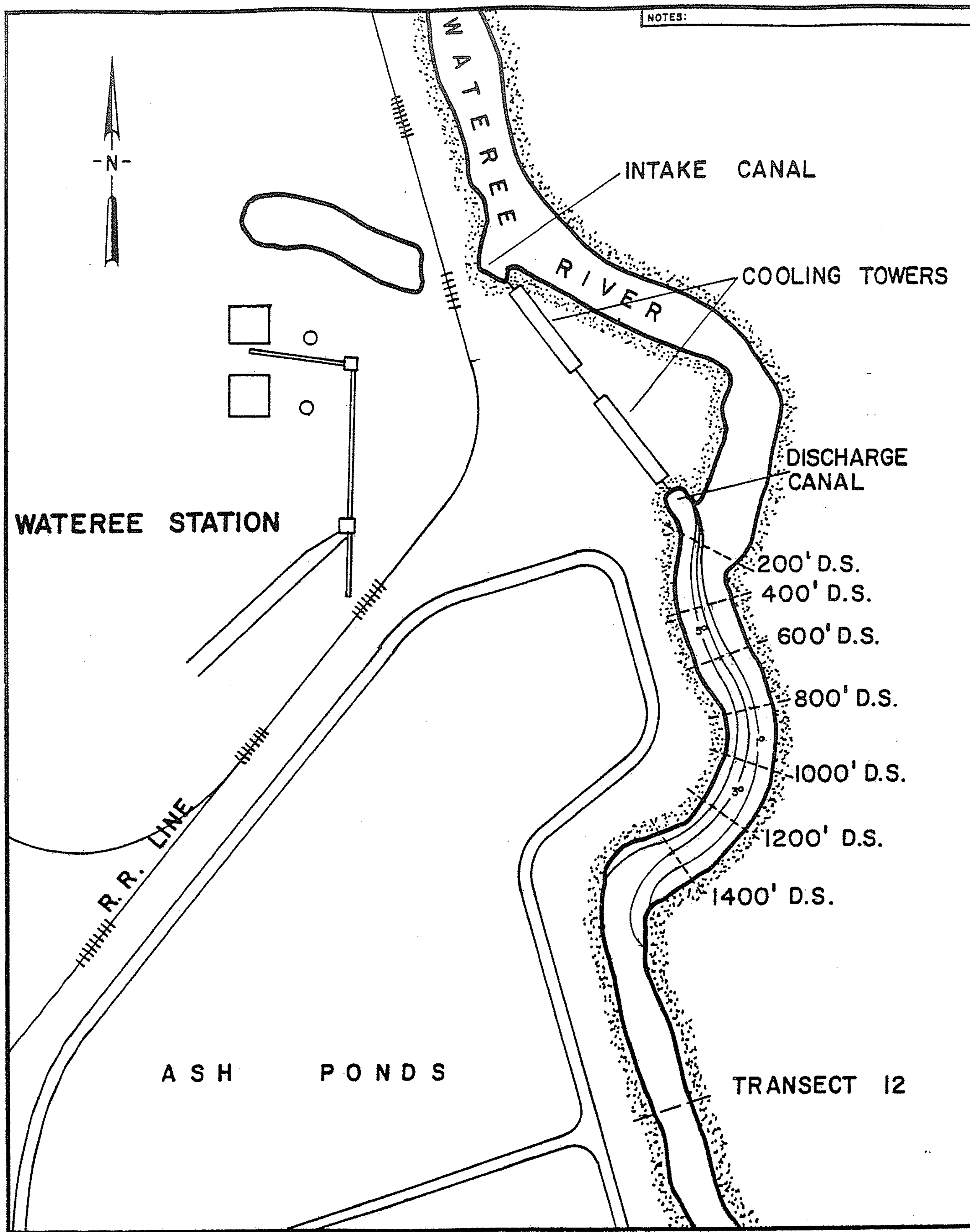
profiles (Figures 21 and 22) and acreages (Table 9) were then developed for plant operating modes at the flows noted in Figures 18 and 20 for design conditions 4 and 6 described earlier (page 31).

The model results describing variation in cooling modes for maintenance of 34.0°C (93.2°F) 0.5 miles downstream have been based on the highly unlikely combination of maximum ambient temperature and continuous maximum discharge ΔT at continuous maximum and average Station production loads.

It should be noted that during September 1976 flow in the Wateree River was less than the 7-day 10-year low flow of 800 cfs on three days (8, 9 and 14th). During these three days, the Station averaged 84% production capacity and a partial closed cycle operation was initiated which held downstream (0.8 miles) temperatures for these three days to less than 28.3°C (83.0°F) at average ambient temperatures of 25.0°C (77.0°F). These data demonstrate the conservative basis of the model predictions and lend confidence to the capability of Wateree Station to maintain 34.0°C (93.2°F) within the 0.5 mile reach during adverse conditions.

C. Chemical Data

The USGS has monitored specific conductance, dissolved oxygen and pH on a continuous basis near the Wateree Station cooling water intake since 1971. These data are summarized on a monthly basis in Tables 10, 11 and 12.



DATE ______

AVERAGE MWe PRODUCTION 472 MWe

% MAXIMUM PRODUCTION 65.5

COOLING MODE :HELPER, MIN. COOL. TOWER EFF.

AVERAGE DISCHARGE △T 7.3°C

AVERAGE AMBIENT TEMPERATURE 30.5°C

WATEREE RIVER FLOW 1600 cfs

FIGURE 22

MODEL PREDICTION OF EXCESS TEMPERATURES FOR AVERAGE STATION PRODUCTION (472 MWe) MAXIMUM AMBIENT TEMPERATURE, AND HELPER MODE COOLING AT 1600cfs RIVER FLOW.

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Table 9. Thermal predictions for extreme model conditions.

	Plant Operating Conditions					
River Flow	Production Load	Condenser ΔT	Cooling Mode	Discharge ΔT	Ambient Temp.	Area Within the 3°C Isotherm
	MWe	°C		°C	°C	Acres
2850	720	15.1	Helper	11.1	30.5	6.2
1600	472	11.3	Helper	7.3	30.5	3.4

Table 10. Wateree Station monthly average specific conductance (micromhos/cm at 25°C) for water years (October thru September) 1971-1976.

Month	Water Year 1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	Six Year Mean
Oct	117 a/	128a/	128 a/	102a/	112a/	105	115
Nov	110 a/	104	134	107	111	112	113
Dec	124 a/	106	114	135	109	100	115
Jan	151 a/	101a/	85 a/	108	92a/	95	105
Feb	95 a/	No data	81 a/	86	70a/	95	85
Mar	80	98a/	84	90	72	94	86
Apr	85 a/	110a/	65a/	87a/	68	101a/	86
May	100	122	88	92	85	115	100
Jun	98 a/	112	81	98	80	107	96
Jul	89 a/	97	84	112	78	102a/	94
Aug	87	107	97	109	91	102a/	99
Sep	107	117	106	105	103a/	119a/	110

a/ Average which did not include a full month's data.

Source: United States Geological Survey, Water Resources Data for South Carolina; 1971, 1972, 1973, 1974, 1975 and 1976.

Table 11. Wateree Station monthly average dissolved oxygen (ppm) for water years (October-September) 1971-1976.

Month	Water Year 1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	Six Year Mean
Oct	7.4 a/	No data	7.3 a/	6.3 a/	7.7	6.5	7.0
Nov	9.4 a/	8.6 a/	8.8	8.2 a/	8.8	7.9	8.6
Dec	9.2 a/	8.9 a/	9.3	9.7	10.8	9.4	9.6
Jan	10.0 b/	8.7 a/	8.1 a/	8.8 a/	9.8 a/	10.2	9.3 b/
Feb	10.0 b/	No data	9.7 a/	9.2 a/	9.0 a/	9.7	9.5 b/
Mar	9.0 a/	9.2 a/	8.8 a/	8.8	9.1 a/	7.9	8.8
Apr	8.6 a/	8.5 a/	8.4 a/	7.9 a/	8.0 a/	8.1 a/	8.2
May	7.0 a/	7.2	7.9	6.8	6.2	7.1	7.0
Jun	6.0 a/	6.5	5.9	6.3	5.5	5.9	6.0
Jul	6.0 a/	6.2	5.8	5.8	5.6	5.7 a/	5.8
Aug	5.8 a/	6.0	6.0	5.5	5.4	6.6 a/	5.9
Sep	6.0	6.3 a/	6.0	6.1	6.2 a/	6.8 a/	6.2

a/ Average which did not include a full month's data.

b/ Dissolved oxygen concentrations were greater than ten (10) ppm and were counted as 10 ppm for calculating average values.

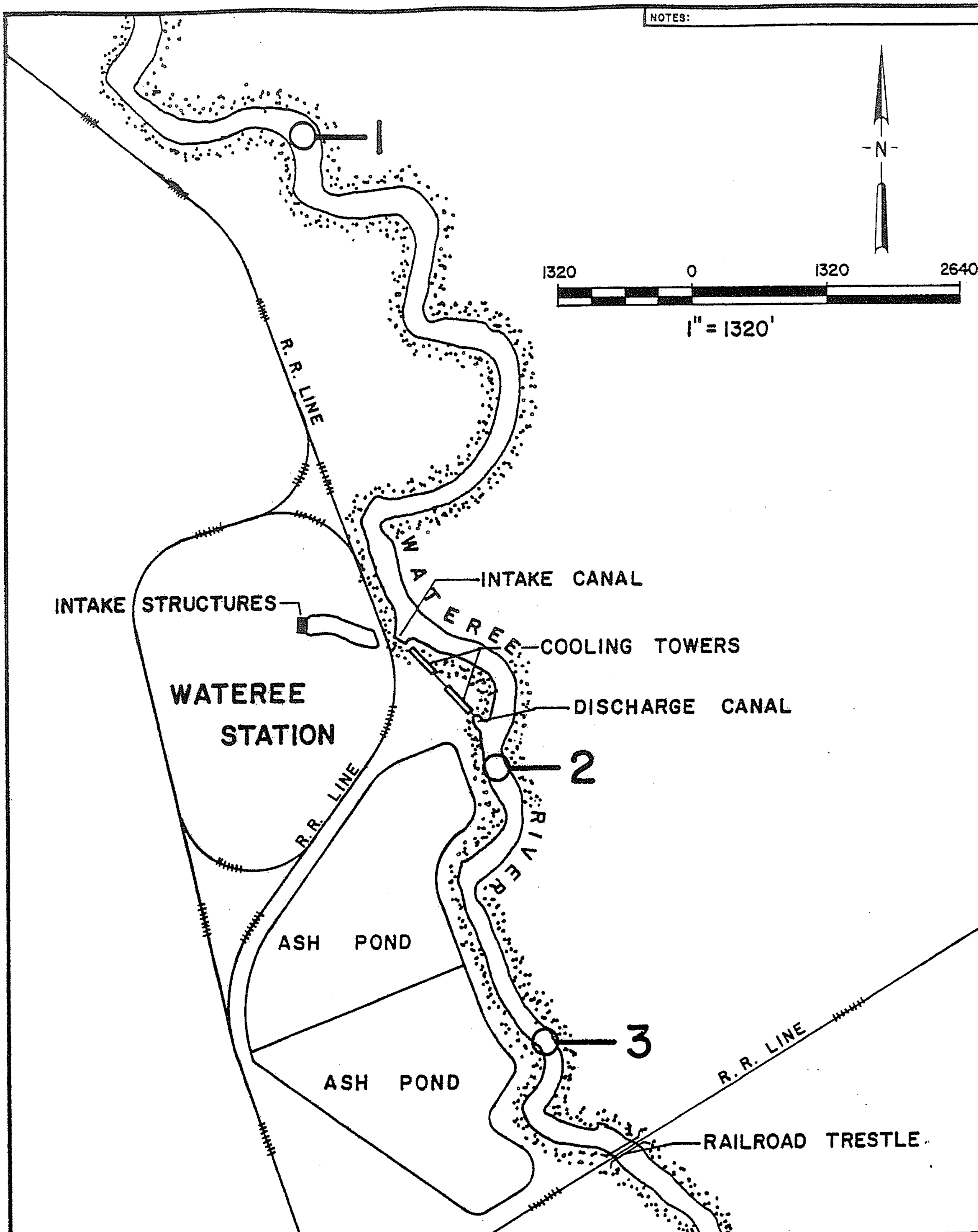
Source: United States Geological Survey, Water Resources Data For South Carolina; 1971, 1972, 1973, 1974, 1975, and 1976.

Table 12. Wateree Station monthly average pH (units) for water years (October-September) 1971-1976.

Month	Water Year						Six Year Mean
	1970-71	1971-72	1972-73	1973-74	1974-75	1975-76	
Oct	No data	6.6 a/	6.7	6.5	6.5	6.6	6.6
Nov	No data	6.9 a/	6.7	6.5	6.4	6.9	6.7
Dec	No data	619	6.5	6.7	6.5	7.0	6.7
Jan	No data	6.8 a/	6.4 a/	6.5	6.6 a/	6.8	6.6
Feb	7.1 a/	No data	6.8 a/	6.4	6.6 a/	6.6	6.7
Mar	6.6	6.9 a/	6.6	6.5	6.5 a/	6.6	6.6
Apr	6.8 a/	6.8 a/	6.4 a/	6.6 a/	6.4	6.6 a/	6.6
May	6.6	6.9	6.5	6.5	6.3	6.8	6.6
Jun	6.5 a/	6.7	6.4 a/	6.6	6.4	6.9	6.6
Jul	6.5 a/	6.7	6.4	6.7	6.4	6.5	6.5
Aug	6.5	6.8	6.5	6.7	6.6	6.6 a/	6.6
Sep	6.8	6.8 a/	6.4	6.5	6.5 a/	6.7 a/	6.6

a/ Average which did not include a full month's data.

Source: United States Geological Survey, Water Resources Data For South Carolina; 1971, 1972, 1973, 1974, 1975, and 1976.



REV.	DATE	BY	DESCRIPTION	APP.

REVISION

SEAL

FIGURE 23

FISH SAMPLING LOCATIONS

SCE&G WATEREE STATION

RICHLAND COUNTY SOUTH CAROLINA

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fish kills downstream. A net (15.2 m in length, 1.8 m in depth and of 1.2 cm square mesh) was set immediately downstream of the sample area to recover fish drifting beneath the surface. All fish collected by this method were preserved immediately in 10% formalin. Rotenone sampling was not continued after September 20, 1976 when water temperature dropped to levels at which rotenone becomes ineffective.

Fish sampling was continued by electrofishing at each location on a monthly basis through February 1977. The scheduled October collection was postponed until November 3, 1976 due to flood conditions. Sampling was conducted after dark with a Smith-Root Type VI Electrofisher and 560 volts of pulsed DC current at a frequency of 60 pulses per second and a pulse width of 4 milliseconds. Five anodes were supported from the bow of the boat at a distance of 2 m from the aluminum boat hull which served as the cathode. All available shoreline habitats were sampled at each location and Location 2 included the discharge canal. The actual number of sampling seconds was recorded at each location. All fish of sufficient size were processed in the field and released. Individuals of selected species (white catfish, blue catfish, channel catfish, white bass, striped bass, redbreast sunfish, bluegill, redear sunfish, spotted sunfish, black crappie and largemouth bass) were identified, weighed (g) and total length measured (mm). These species were selected on the basis of trophic level and potential economic importance for evaluation of body condition (K-factor). Individuals of other species were identified and total weight determined. Small individuals were preserved in 10% formalin and taken to the laboratory for processing.

All fish collected were examined for the presence of external parasites and disease.

Water temperature was recorded at each sampling location at the time of sample collection. Water level (gage height at USGS Eastover Station, #02148315) was determined for each sampling date.

b. Laboratory Procedures

All specimens that were preserved in the field were transferred to 50% isopropyl alcohol after two weeks in formalin. Preserved specimens were then processed as stated above and representatives of each species were retained in a permanent reference collection.

c. Data Analysis

Relative abundances of fish collected by rotenone sampling and electrofishing were expressed in terms of catch per unit of sampling effort. Care was taken to insure uniformity of sampling procedures among dates and locations for each collection method. Relative abundance of fish collected with rotenone was expressed as individuals/61 m section of shoreline and of fish collected by electrofishing as individuals/1000 sampling seconds.

Species diversity index values were calculated to evaluate both rotenone and electrofishing data at each location. Also, index values were computed for all fish (methods combined) at each location. All collections from each location were grouped in order to calculate a pooled diversity index. Bechtel and Copeland (1970) stated that a pooled index is probably more representative of an area because the relative abundance of each species actually present in the area is more closely approximated in a pooled collection than in individual collections. In the present study several collections contained insufficient numbers for calculation of reliable index values, therefore, values were calculated for pooled collections at each location. Mean diversity ($\bar{d}$) was computed using the Shannon-Weaver function as refined by Lloyd, Zar and Karr (1968) and reported by USEPA (1973). The formula is:

$$\bar{d} = C/N\ (N \log_{10} N - \Sigma\, n_i \log_{10} n_i)$$

where C = 3.321928, N = total number of individuals and n = total number of individuals in the i^{th} species.

Coefficient of condition or K-factor (K = Weight x 10^5 / Length^3) was calculated for individuals of those species for which individual lengths and weights were recorded. Individuals of each species were classified according to length in 25 mm increments and individuals less than 50 mm were excluded. Least Squares analyses were performed on each species-size combination that contained eight or more specimens to determine if there were statistically significant differences ($p \leq 0.05$) in the coefficient of condition (K-factor) among sampling locations. Comparisons which included both live and preserved fish were made only when statistical analysis indicated no significant difference between these groups.

Table 13. Scientific and common names of fish species mentioned in this report.

Family and Scientific Name	Common Name
Lepisosteidae	Gars
Lepisosteus osseus	Longnose gar
Amiidae	Bowfins
Amia calva	Bowfin
Anguillidae	Freshwater eels
Anguilla rostrata	American eel
Clupeidae	Herrings
Alosa mediocris	Hickory shad
Dorosoma cepedianum	Gizzard shad
Dorosoma petenense	Threadfin shad
Esocidae	Pikes
Esox americanus	Redfin pickerel
Esox niger	Chain pickerel
Cyprinidae	Minnows and carps
Cyprinus carpio	Carp
Hybognathus nuchalis	Silvery minnow
Notemigonus crysoleucas	Golden shiner
Notropis maculatus	Taillight shiner
Notropis niveus	Whitefin shiner
Notropis petersoni	Coastal shiner
Catostomidae	Suckers
Minytrema melanops	Spotted sucker
Ictaluridae	Freshwater catfishes
Ictalurus catus	White catfish
Ictalurus furcatus	Blue catfish
Ictalurus natalis	Yellow bullhead
Ictalurus nebulosus	Brown bullhead
Ictalurus punctatus	Channel catfish
Pylodictis olivaris	Flathead catfish
Aphredoderidae	Pirate perches
Aphredoderus sayanus	Pirate perch
Poeciliidae	Livebearers
Gambusia affinis	Mosquitofish

Table 13. (Continued)

Family and Scientific Name	Common Name
Percichthyidae	Temperate basses
Morone chrysops	White bass
Morone saxatilis	Striped bass
Centrarchidae	Sunfishes
Centrarchus macropterus	Flier
Lepomis auritus	Redbreast sunfish
Lepomis cyanellus	Green sunfish
Lepomis gibbosus	Pumpkinseed
Lepomis gulosus	Warmouth
Lepomis macrochirus	Bluegill
Lepomis marginatus	Dollar sunfish
Lepomis microlophus	Redear sunfish
Lepomis punctatus	Spotted sunfish
Micropterus salmoides	Largemouth bass
Pomoxis annularis	White crappie
Pomoxis nigromaculatus	Black crappie
Percidae	Perches
Etheostoma fusiforme	Swamp darter
Etheostoma olmstedi	Tessellated darter
Perca flavescens	Yellow perch
Mugilidae	Mullets
Mugil cephalus	Striped mullet

importance to the sport fisherman and include the catfishes, temperate basses, sunfishes and the yellow perch. Sport fishing creel census data were not available for the Wateree River, so the relative importance of these species in the sport fishing catch is uncertain. Most species may be considered forage fish at some point in their life histories. Species included in this group here are only those utilized as forage during most or all of their life stages. Forage fishes include shad (Dorosoma sp.), minnows (Hybognathus sp. and Notropis sp.), mosquitofish and darters. Rough species are those that have little or no appeal to the commercial or sport fisherman and are too large as adults to be utilized as forage. The longnose gar, bowfin, hickory shad, carp and spotted sucker are considered rough species in this report. Commercial fishing activity is limited on the Wateree River and no catch statistics were available from the South Carolina Wildlife and Marine Resources Department. The catfish group is probably the most important to the commercial fisherman and members of this group are here categorized as sport species.

Sport species comprised 32.4% of the total catch at Location 2 (discharge) and 21.0% and 14.2% at Locations 3 (downstream) and 1 (upstream), respectively (Table 14). The channel catfish was the most abundant sport fish followed by the bluegill, spotted sunfish and largemouth bass. Sport species were second to forage species in relative abundance and represented 21.5% of the total number.

Members of the forage fish category comprised 71.8% of the total number collected. Forage species constituted 82.4%, 76.0% and

48.7% of the total catch at Locations 1, 3 and 2, respectively (Table 14). The most numerous forage fishes, in order of decreasing relative abundance, were: coastal shiner, whitefin shiner, silvery minnow, gizzard shad and threadfin shad.

Rough fish were collected in relatively low numbers throughout the study and represented only 6.7% of the total catch (Table 14). The longnose gar, carp and spotted sucker were the most numerous of the rough species. Rough fish made up 18.9% of the total catch at the discharge (Location 2) and 3.4% and 3.0% of the catches at Locations 1 and 3, respectively (Table 14).

In general, sport species constituted a larger portion of fish collections at thermal discharge and thermally mixed sampling locations than at the ambient temperature location. Forage fish comprised the most abundant group at all locations but were least abundant at the discharge location, and most abundant at the ambient location. The rough fish group was the least abundant category at all sampling locations but made up a larger part of the discharge collection than upstream and downstream collections.

b. Rotenone Data

During the warm weather months (June through September), fish were collected by rotenone sampling. This collection technique was effective in collecting adult and juvenile fish when water temperatures were sufficiently high to maintain toxicity. Rotenone mixed rapidly and thoroughly to sample all available habitats within the designated sample area. Success of rotenone sampling was closely related to water level which fluctuated throughout the study due to variable discharge rates from Wateree Dam 66 miles upstream. Water levels varied as much as 10.2 feet among rotenone sampling dates, and catch rates were lowest during extremes of high and low levels (Table 15). Changes in water level apparently displaced or dispersed fish so that they were less available for collection.

A total of 905 individual fish representing 27 species were collected by rotenone sampling (Table 16). Additionally, a number of small, immature specimens identified as Lepomis sp. and Notropis sp. were obtained. Although the small individuals of these unspecified genera were not included in calculation of catch rates and relative abundance, their presence indicates successful reproduction by these fish occurred within the study area. Mean total catch rates were lowest at Location 2 (Table 16), which was situated within the direct influence of the thermal outfall. However, catch rates were highest at Location 3 which was situated downstream of the discharge within the area of mixed discharge and ambient water.

Relative abundance of sport species was highest at Location 3 (44.0 individuals/unit of effort) and lowest at Location 2 (9.3 individuals/unit of effort) (Table 16). The channel catfish was the most abundant sport species collected at each sampling location. This species was most numerous at Location 3 followed by Locations 1 and 2, respectively. The bluegill and largemouth bass exhibited the same pattern of

Table 15. Water level (ft.) and temperature (°C) recorded in conjunction with fish sampling activities near Wateree Station, June 1976 through February 1977.

	Date								
	29 Jun	26 Jul	23 Aug	20 Sep	3 Nov	29 Nov	29 Dec	26 Jan	7 Feb
Location 1									
Water Level a/	14.90	7.20	4.70	6.80	13.30	8.00	13.60	14.60	5.65
Water Temp.	26.0	28.5	27.0	25.0	13.5	12.0	8.0	3.5	6.0
No. Individuals	11	86	15	68	24	237	b/	9	159
No. Species	5	15	3	10	6	17		4	7
Location 2									
Water Level	14.90	7.20	4.70	6.80	13.30	8.00	13.60	14.60	5.65
Water Temp.	32.0	39.0	34.1	27.8	15.1-25.0 c/	15.0-17.0	10.0-16.5	5.0-12.0	10.0-19.0
No. Individuals	17	22	10	24	73	102	55	34	116
No. Species	10	5	6	8	11	14	14	10	16
Location 3									
Water Level	14.90	7.20	4.70	6.80	13.30	8.00	13.60	14.60	5.65
Water Temp.	29.4	30.0	28.4	25.0	14.0	13.0	8.5	4.0	9.5
No. Individuals	b/	235	166	251	16	155	35	19	92
No. Species		16	11	13	7	13	9	9	17

a/ USGS Gage height @ Station 02148315.

b/ No data collected.

c/ Represents range of water temperature @ Location 2 for electrofishing.

Table 16. Catch rates (individuals/61 m section of shoreline) of fish collected by rotenone sampling near Wateree Station on each sample date, June 1976 through September 1976.

Species	29 June			26 July			23 August Locations			20 September			Mean		
	1	2	3 a/	1	2	3	1	2	3	1	2	3	1	2	3
Sport Species															
White catfish	–	–		–	–	1	–	–	–	–	–	–	–	–	0.3
Blue catfish	–	–		–	–	2	–	–	–	–	–	–	–	–	0.7
Yellow bullhead	–	–		–	–	–	–	1	–	–	–	–	–	0.3	–
Brown bullhead	1	2		–	–	–	–	–	–	–	–	–	0.3	0.5	–
Channel catfish	7	2		20	3	16	–	1	33	8	8	31	8.8	3.5	26.7
Flathead catfish	–	–		1	2	–	–	–	–	–	6	4	0.5	2.0	1.3
White bass b/	–	1		–	–	–	–	–	–	1	–	–	0.3	0.3	–
Sunfish (*Lepomis* sp)	–	3		–	13	64	1	2	6	2	–	11	0.8	4.5	27.0
Redbreast sunfish	–	–		–	–	1	–	–	–	–	–	–	–	–	0.3
Green sunfish	–	1		–	–	–	–	–	–	–	–	–	–	0.3	–
Warmouth	–	1		1	2	7	–	–	3	–	–	2	0.3	0.8	4.0
Bluegill	–	1		8	–	4	–	–	–	–	–	6	2.0	0.3	3.3
Redear sunfish	–	1		–	1	–	–	1	4	–	–	1	–	0.8	1.7
Spotted sunfish	–	–		1	–	1	–	–	1	–	–	1	0.3	–	1.0
Largemouth bass	–	–		1	1	6	3	1	3	–	1	1	1.0	0.8	3.3
Black Crappie	–	–		–	–	2	–	–	2	–	–	–	–	–	1.3
TOTAL	8	9		32	9	40	3	4	46	9	15	46	13.0	9.3	44.0
Forage Species															
Gizzard shad	1	–		16	–	13	–	–	5	7	2	9	6.0	0.5	9.0
Threadfin shad	–	2		4	–	26	–	–	–	7	2	36	2.8	1.0	20.7
Silvery minnow	–	–		4	–	18	–	1	5	2	–	–	1.5	0.3	7.7
Shiner (*Notropis* sp) b/	–	–		–	–	–	–	–	–	15	–	–	3.8	–	–
Taillight shiner	–	–		1	–	21	–	–	2	–	–	1	0.3	–	8.0
Whitefin shiner	1	1		–	–	–	–	–	–	7	2	14	2.0	0.8	4.7
Coastal shiner	–	–		21	–	50	9	–	101	16	2	133	11.5	0.5	94.7
Mosquitofish	–	–		2	–	1	2	–	–	1	1	–	1.3	0.3	0.3
Swamp darter	–	–		1	–	–	–	–	–	–	–	–	0.3	–	–
Tessellated darter	–	–		–	–	2	–	–	–	–	–	1	–	–	1.0
TOTAL	2	3		49	–	131	11	1	113	40	9	194	25.5	3.3	146.0
Rough Species															
Longnose gar	–	2		3	–	–	–	3	1	1	–	–	1.0	1.3	0.3
Hickory shad	1	–		2	–	–	–	–	–	–	–	–	0.8	–	–
Carp	–	–		–	–	–	–	–	–	1	–	–	0.3	–	–
TOTAL	1	2		5	–	–	–	3	1	2	–	–	2.0	1.3	0.3
GRAND TOTAL	11	14		86	9	171	14	8	160	51	24	240	40.5	13.8	190.3

a/ No data collected.

b/ Not included in totals.

distribution among locations. Flathead catfish were most abundant at the discharge Location 2, followed by Locations 3 and 1. All sport species collected upstream of the discharge were also collected at either the discharge or downstream locations. Seven sport species were collected at Locations 2 and/or 3 but not at the upstream ambient location (Location 1). However, relative abundances of these seven species (white catfish, blue catfish, yellow bullhead, redbreast sunfish, green sunfish, redear sunfish and black crappie) were low throughout the study.

Results of rotenone collection of forage fish suggest the same pattern of relative abundance among locations as did sport fish data (Table 16). Catch rates of forage species were highest at Location 3 followed by Location 1. Low catch rates at the discharge (Location 2) suggested avoidance of the immediate discharge area during the warmer months. The most numerous forage species, in order of decreasing relative abundance, were: coastal shiner, threadfin shad and gizzard shad. Each of these species were most abundant at Location 3 and least abundant at Location 2. The swamp darter was the only forage species encountered upstream but not downstream of the discharge, however, only one individual was collected. The tessellated darter was the only forage species collected at a thermally influenced location but not at the upstream ambient location. Since only three specimens were collected, the tessellated darter is not considered an important forage species.

Three rough species (longnose gar, carp and hickory shad) were collected by rotenone sampling (Table 16). Relative abundances of these species did not follow the same pattern exhibited by sport and forage fish data. The longnose gar was the most numerous rough fish and was collected in largest numbers at Location 2 and lowest numbers at Location 3. The carp and hickory shad were collected at Location 1 only. The occurrence of these two species at Location 1 resulted in higher total catch rates of rough species at the upstream location than either of the thermally influenced locations. Low numbers of rough fish in rotenone collections preclude reliable conclusions concerning distribution of these species.

In general, rotenone sampling data indicate that most species preferred locations other than the immediate thermal discharge area during the warmer months. High catch rates and large numbers of species at the location within the area of mixed discharge and ambient water indicate that any influence of the thermal effluent on fish community composition and abundance occurred in only a small portion of the river.

c. Electrofishing Data

Fish were collected during the colder months (November through February) by electrofishing. This sampling procedure was conducted at the same locations utilized for rotenone sampling. Electrofishing allows the sampling of a longer length of shoreline and more available habitats than is practical with rotenone sampling. Both electrofishing and rotenone sampling were successful in collecting a large number of species and a variety of size groups of each species.

As was observed with rotenone sampling, the effectiveness of electrofishing was related to water level which fluctuated as much as 9.0 feet among electrofishing collection dates (Table 15). Numbers of fish collected were inversely proportional to water level.

A total of 1125 individual fish of 29 species was collected by electrofishing (Table 17). Mean total catch rate was highest at Location 1 (93.9 individuals/1000 sampling seconds) followed by Location 2 (59.5 individuals) and Location 3 (59.3 individuals).

Relative abundance of sport species was highest at the discharge (Location 2) and higher at Location 3 than Location 1 (Table 17). The bluegill was the most frequently collected sport species. Catch rates of this species were highest at Location 3 followed by Location 2 and Location 1. Relative abundance of the spotted sunfish followed the same pattern of distribution among locations as the bluegill. Largemouth bass were most abundant at Location 3 and similar in abundance at Locations 2 and 1. Three sport species (white bass, striped bass and pumpkinseed) were most numerous at the discharge Location 2 on every date they were collected. White bass were collected only during January and February and were observed at all locations. Striped bass were collected from November through February and only one individual was collected at Location 3, all others were from Location 2. Several sport species were collected at only one location, however, each of these species was represented by less than three individuals.

Table 17. Catch rates (individuals/1000 sampling seconds) of fish collected by electrofishing near Wateree Station on each sample date, November 1976 through February 1977.

Species	3 November			29 November			29 December			26 January			7 February			Mean		
	Locations																	
	1	2	3	1	2	3	1 a/	2	3	1	2	3	1	2	3	1	2	3
Sport Species																		
Chain pickerel	-	-	-	-	-	-		-	-	-	-	-	0.7	-	-	0.2	-	-
Channel catfish	4.2	1.6	2.8	0.9	1.6	-		-	-	-	-	-	-	0.7	0.7	1.3	0.8	0.7
Flathead catfish	-	-	-	-	-	-		0.8	-	-	-	-	-	1.5	-	-	0.5	-
White bass	-	-	-	-	-	-		-	-	1.0	1.7	1.0	-	5.9	1.5	0.3	1.5	0.5
Striped bass	-	-	-	-	4.0	-		7.5	-	-	2.5	-	-	1.5	0.7	-	3.1	0.1
Redbreast sunfish	-	1.6	-	1.8	-	1.9		1.7	-	-	-	-	-	-	-	0.5	0.7	0.4
Pumpkinseed	-	5.5	-	1.8	5.7	2.9		0.8	-	-	1.7	-	-	0.7	-	0.5	2.9	0.6
Warmouth	-	-	-	0.9	-	2.9		-	-	-	-	-	-	-	-	0.2	-	0.6
Bluegill	-	4.7	-	7.2	4.0	12.5		2.5	1.1	-	0.8	1.0	3.0	3.0	2.9	2.6	3.0	3.5
Dollar sunfish	-	-	-	-	-	-		-	-	-	-	-	-	-	0.7	-	-	0.1
Redear sunfish	-	0.8	-	-	-	1.9		2.5	1.1	-	0.8	-	-	0.7	-	-	1.0	0.6
Spotted sunfish	1.4	6.2	1.4	3.2	-	4.8		2.5	3.3	-	-	1.0	-	1.5	1.5	1.2	2.0	2.4
Largemouth bass	-	1.6	-	1.8	1.6	1.0		-	2.2	-	-	-	0.7	-	0.7	0.6	0.6	0.9
Black crappie	-	-	-	0.9	-	-		-	-	-	-	-	-	-	-	0.2	-	-
Yellow perch	-	-	-	-	0.8	-		-	-	-	-	-	-	1.5	-	-	0.5	-
TOTAL	5.6	23.0	4.2	18.5	17.7	27.9		18.3	7.7	1.0	7.5	3.0	4.4	17.0	8.7	7.4	16.5	10.3
Forage Species																		
Gizzard shad	4.2	-	2.8	0.9	2.4	4.8		11.6	-	-	4.2	-	3.7	20.1	8.8	2.2	7.7	3.3
Threadfin shad	-	-	-	0.9	4.0	-		4.1	-	-	-	-	-	-	-	0.2	1.6	-
Silvery minnow	-	-	-	26.3	0.8	26.1		3.3	1.1	-	3.3	1.0	36.7	17.1	7.4	15.8	4.9	7.1
Golden shiner	-	-	-	-	-	-		-	-	-	-	-	-	-	2.2	-	-	0.4
Taillight shiner	-	-	-	-	-	-		-	-	-	-	-	-	-	1.5	-	-	0.3
Whitefin shiner	20.9	14.1	8.4	91.5	19.4	29.9		1.7	14.2	6.0	6.7	8.9	50.2	5.2	10.3	42.2	9.4	14.3
Coastal shiner	1.4	0.8	2.8	70.7	21.9	54.1		0.8	10.9	-	-	3.0	21.7	14.9	20.6	23.5	7.7	18.3
Tessellated darter	-	-	-	-	-	-		-	-	-	-	-	-	-	0.7	-	-	0.1
TOTAL	26.5	14.9	14.0	190.3	48.5	114.9		21.5	26.2	6.0	14.2	12.9	112.3	57.3	51.5	83.8	31.3	43.9
Rough Species																		
Longnose gar	1.4	17.2	1.4	0.9	9.8	4.8		-	3.3	-	1.7	1.0	2.2	2.2	3.7	1.1	6.2	2.8
Bowfin	-	-	-	-	-	-		-	-	1.0	-	-	-	-	-	0.3	-	-
Hickory shad	-	-	-	0.9	-	-		-	-	-	-	-	-	-	-	0.2	-	-
Carp	-	3.1	2.8	0.9	3.2	1.9		5.0	1.1	-	5.0	1.0	-	2.2	0.7	0.2	3.7	1.5
Spotted sucker	-	-	-	2.7	-	-		0.8	-	1.0	-	1.0	-	7.4	2.9	0.9	1.6	0.8
Striped mullet	-	-	-	-	0.8	-		-	-	-	-	-	-	-	-	-	0.2	-
TOTAL	1.4	20.3	4.2	5.4	13.8	6.7		5.8	4.4	2.0	6.7	3.0	2.2	11.8	7.3	2.8	11.7	5.1
GRAND TOTAL	33.5	57.2	22.4	214.2	80.0	149.5		45.6	38.3	9.0	28.4	18.9	118.9	86.1	67.5	93.9	59.5	59.3
NO. INDIVIDUALS	24	73	16	237	102	155		55	35	9	34	19	159	116	92	107.3	76.0	63.2

a/ No data collected

Electrofishing catch rates of forage fish were highest at Location 1 followed by Location 3 and Location 2 (Table 17). The whitefin shiner and coastal shiner were the most numerous forage fishes. Both of these species were most abundant at Location 1 and least abundant at Location 2. The silvery minnow exhibited the same pattern of relative abundance. The gizzard shad and threadfin shad were most numerous at the discharge (Location 2). Gizzard shad were common at all locations and numbers were similar at Locations 1 and 3. Threadfin shad were not collected at Location 3 by electrofishing and were not present in any collection after December 29. The golden shiner, taillight shiner and tessellated darter were taken only at Location 3 and only on one sample date.

The longnose gar, carp and spotted sucker were the most abundant rough species (Table 17). Catch rates of rough fish were highest at the discharge (Location 2) and lowest at the upstream location (Location 1). Relative abundances of each of the longnose gar, carp and spotted sucker were highest at Location 2. Longnose gar and carp were more abundant at Location 3 than Location 1 and catch rates of the spotted sucker were similar among these two locations. Other rough species were the bowfin, hickory shad and striped mullet, however, only one individual of each was collected.

Electrofishing data indicates that members of the sport and rough fish categories preferred discharge over non-discharge areas during the colder months. Forage fish as a group preferred non-discharge areas.

d. Species Diversity

Numbers of fish species collected by rotenone sampling ranged from 17 at Location 2 (discharge) to 20 at Location 3 (downstream) (Table 18). Electrofishing data were even more uniform in numbers of species with 20 species at Locations 1 and 2 and 21 at Location 3. When all methods were combined, 25 species were observed at Locations 1 and 2 and 27 at Location 3.

The Shannon-Weaver species diversity index value calculated for pooled rotenone collections at each sampling location was 3.5645 at Location 2 (discharge), 3.1564 at Location 1 (upstream) and 2.6103 at Location 3 (downstream). The diversity index value computed for pooled electrofishing collections was 3.7373, 3.0981 and 2.2784 for Locations 2, 3 and 1, respectively. An overall diversity index value was calculated for each location by pooling all collections (both methods) at each location. Highest overall diversity was calculated for Location 2 (3.7981) followed, in descending order, by Location 3 (3.0722) and Location 1 (2.8547). Large catches of whitefin and coastal shiners were, in part, responsible for lower diversity at Location 3 for pooled rotenone collections and at Location 1 for pooled electrofishing collections. Catches of these species were not large at Location 2 with either method. This contributed to more even distribution of individuals among the species which resulted in higher species diversity.

Generally, these data indicate that species diversity within the fish community was as great or greater in areas influenced by the thermal effluent as in unaffected areas.

Table 18. Diversity of fish collected near Wateree Station during June 1976 through February 1977.

Sampling Method	Location 1 (Upstream)	Location 2 (Discharge)	Location 3 (Downstream)
Rotenone			
No. of Species	19	17	20
No. of Individuals	162	55	571
Diversity Index	3.1564	3.5645	2.6103
Electrofishing			
No. of Species	20	20	21
No. of Individuals	429	380	316
Diversity Index	2.2784	3.7373	3.0981
All Methods			
No. of Species	25	25	27
No. of Individuals	591	435	887
Diversity Index	2.8547	3.7981	3.0722

3. Coefficient of Body Condition

Results of statistical comparisons of coefficient of body condition are shown in Table 19. Condition factors were calculated for several species (white catfish, blue catfish, channel catfish, white bass, striped bass, redbreast sunfish, bluegill, redear sunfish, spotted sunfish, black crappie and largemouth bass). However, only channel catfish, bluegill and spotted sunfish occurred in sufficient numbers at each sampling location to allow comparison of any species-size combinations. Although significant differences ($p \leq 0.05$) are indicated for three species-size combinations, less than three individuals were included in the mean for at least one location in each case. Also, for each species-size combination tested, at least one location was represented by three or less individuals. The overall results of these comparisons suggest that there were only slight, if any, differences in condition factors among sampling locations. The numbers of specimens involved make a definitive statement questionable.

4. Parasites and Diseases

Five types of external parasites were observed on nine host fish species during the study period (Table 20). Both frequency of occurrence and intensity of infestations were low throughout the study. No extensive physical damage or mortality due to parasitic infestations were encountered. Parasites occurred on fish from locations within and outside the influence of the thermal discharge. No evidence of enhancement of parasitic infestations by the thermal effluent was obtained.

Table 19. Results of Least Squares analysis of fish coefficient of condition (K-factor) data to determine significant differences ($p \leq 0.05$) among sampling locations near Wateree Station, June 1976 through February 1977.

Species	Size group (mm)	F Value	p	Significant differences between sampling locations
Channel catfish	50- 74	4.761	0.0155	1,3 > 2
Channel catfish	75- 99	5.245	0.0196	3 > 1
Channel catfish	100-124	1.165	n.s.[a/]	-
Channel catfish	125-149	4.665	n.s.	-
Channel catfish	150-174	0.811	n.s.	-
Bluegill	50- 74	1.200	n.s.	-
Bluegill	75- 99	0.219	n.s.	-
Bluegill	100-124	2.019	n.s.	-
Spotted sunfish	75- 99	10.277	0.0024	2,3 > 1
Spotted sunfish	100-124	1.069	n.s.	-

a/ Not significant ($p > 0.05$).

Table 20. Percent frequency of occurrence of external parasites on fish collected near Wateree Station during June 1976 through February 1977.

Host Species	Parasite	Percent Infestation Location 1	Location 2	Location 3
Bowfin	Argulus	100.00	-	-
Silvery minnow	Uvulifer	34.5	75.8	58.1
Channel catfish	Leech	-	5.3	-
White bass	Epistylis	-	9.1	-
Striped bass	Epistylis	-	5.3	-
Bluegill	Lernaea	5.0	10.0	6.9
	Epistylis	-	-	3.4
Redear sunfish	Lernaea	-	-	25.0
Spotted sunfish	Lernaea	16.7	-	-
Largemouth bass	Lernaea	-	14.3	-
	Uvulifer	-	14.3	-
	Epistylis	-	-	7.1

One infestation of fish lice (Argulus) was observed on a bowfin collected from Location 1. This parasitic copepod punctures the skin of the host and feeds on blood (Bowen and Putz, 1966). Damage to fish populations occur if infestations of Argulus become heavy, however, like other parasitic copepods, its complicated life cycle is frequently interrupted in nature and it rarely becomes abundant enough to injure fish severely (Davis, 1965). Argulus is inactive below 8.0°C (46.4°F) and can withstand temperatures to 43.0°C (109.4°F), the optimum temperature is 28.0°C (82.4°F) (Bowen and Putz, 1966). Naturally occurring water temperatures are suitable for the development of this parasite in the Wateree River. No fish lice were observed on fish collected from the thermal plume.

The anchor worm (Lernaea), another parasitic copepod, was encountered at all sampling locations. Host species for Lernaea were the bluegill, redear sunfish, spotted sunfish and largemouth bass. Frequency of occurrence and intensity of infestations were similar among sampling locations. Embryonic development of the anchor worm does not occur below 14.0°C (57.2°F) or above 33.0°C (91.4°F), and the optimum range is 23.0-30.0°C (73.4-86.0°F) (Bowen and Putz, 1968). Ambient Wateree River temperatures are suitable for the development of Lernaea.

Black grub (Uvulifer) was a frequent parasite of the silvery minnow at all sampling locations, and was observed on one largemouth bass at Location 3. This parasite is the encysted metacercarial stage of a trematode fluke (Huggins, 1972). Black grubs are widespread and common, particularly among minnows. A snail and fish are intermediate hosts, the final host being a fish-eating bird (Huggins, 1972).

Redsore (Epistylis) is a stalked, ciliated protozoan that is not an obligate parasite, but uses the host as an attachment site (Rogers, 1972). This parasite was found on only four fish during the study. Mortalities associated with infestations of this organism are probably due to secondary bacterial infections. Epistylis is a commonly occurring parasite in the Southeast, and is associated with high organic content in the water with no apparent occurrence correlation to season or temperature (Rogers, 1970). Rogers (1972) reports that Epistylis has been found during all months of the year, but is most prevalent during the winter and spring.

One channel catfish collected at Location 2 exhibited an infestation of parasitic leeches.

5. Spawning Characteristics

Spawning characteristics of some of the more abundant Wateree River fish species have been summarized from the literature and are presented in Table 21. This information along with data from USEPA (1973) is the basis for the following discussion.

The most important environmental factors influencing fish spawning season are day-length and temperature (Hynes, 1972). All species in the area of Wateree Station can be classified as spring and/or summer spawners. Most spawning activity probably occurs during the April through June period with May being the peak month. The exact

Table 21. (Continued)

Species	Spawning Season and Temperature	Fecundity	Spawning Habitat	Method of Spawning
Striped bass	April-June (Lippson and Moran, 1974)	68,000-4,536,800 (Goodson, 1966)	Tidal fresh and slightly brackish rapidly flowing water (Lippson and Moran, 1974) Santee-Cooper population spawns in Congaree and Wateree Rivers (May and Fuller, 1961)	Pelagic eggs deposited in rapidly flowing water, eggs are semi-demersal in still water (Lippson and Moran, 1974)
Redbreast sunfish	June-July (17-28C) (Lippson and Moran, 1974)	963-8250 (Davis, 1972)	Sheltered sand-gravel substrate in less than 15 inches of water (Davis, 1972)	Demersal eggs deposited in nest (Lippson and Moran, 1974)
Pumpkinseed	May-August (16-27C) (Lippson and Moran, 1974)	600-2923 (Hubbell, 1966)	Gravel, sand or clay bottom in less than five feet of water (Hubbell, 1966)	Demersal eggs are deposited in nest (Lippson and Moran, 1974) and guarded by male during incubation (Hubbell, 1966)
Bluegill	May-August (16-27C) (Lippson and Moran, 1974)	2360-49,400 (Emig, 1966)	Shallow water with little vegetation (Lippson and Moran, 1974)	Adhesive eggs deposited in nest and guarded by male (Emig, 1966)
Redear sunfish	Spring and fall (Emig, 1966)	Unknown	Sand, gravel or mud substrate in water to 10 feet deep (Emig, 1966)	Eggs are deposited in a nest (Emig, 1966)
Spotted sunfish	Spring and early summer (Pflieger, 1975)	Unknown	Shallow water in vegetation over sand and gravel bottom (Pflieger, 1975)	Courtship, spawning and nest defense are typical of sunfishes (Pflieger, 1975)
Largemouth bass	May-July (15.5-22C) (Lippson and Moran, 1974)	2000-94,157 (Emig, 1966)	Variety of bottom types where there is little or no current (Pflieger, 1975)	Demersal adhesive eggs deposited in nest (Lippson and Moran, 1974) Male guards eggs and fry (Pflieger, 1975)

timing of spawning activities varies among species. The striped bass is one of the earliest spawners encountered and probably begins spawning in April. The carp and other cyprinid species also begin breeding in April, although the carp may spawn over several months. Catfish species spawn from May through July, with the channel catfish spawning earlier than the flathead. Members of the sunfish family (redbreast sunfish, pumpkinseed, bluegill, redear sunfish, spotted sunfish and largemouth bass) begin spawning about May and some, such as the bluegill, pumpkinseed and redear sunfish may continue to spawn for several months. The redear sunfish has been reported to have a secondary spawning period in the fall in some areas (Emig, 1966). Species with extended spawning seasons usually have a shorter period of peak activity.

Most of the species in the Wateree River are local residents which occur in the same general area throughout the year. These species are non-migratory and do not travel long distances to spawn. The striped bass is an anadromous species which typically ascends rivers and may travel considerable distance to breed. The landlocked striped bass populations which inhabit Lakes Marion and Moultrie migrate up the Congaree River and, to a much lesser extent, the Wateree River to spawn (May and Fuller, 1962). Other migratory species encountered in the area are the hickory shad (Mansueti and Hardy, 1967) and the white bass (Chadwick, et al., 1966); however, these species make up a small part of the fish community.

Spawning habitat preference and method of gamete deposition vary widely among species. Two main types of spawning behavior occur among Wateree River fishes. In the first type of spawning behavior, the gametes are released in a somewhat random fashion and either float in the water or more typically, sink to the bottom and adhere to contacted objects. Species with sinking adhesive eggs usually spawn in shallower water over vegetation or some other object, while the species with floating eggs usually spawn where there is some current. Species which exhibit this type of breeding behavior include the longnose gar, gizzard shad, threadfin shad, carp, minnows and shiners and the striped bass. All of these species except the striped bass have demersal and/or adhesive eggs which do not normally drift with water currents. Striped bass eggs are pelagic in flowing water and semi-demersal in still water. Incubation of striped bass eggs must occur in flowing water or they sink to the bottom, become silt-covered and do not hatch. After hatching, larvae of species of the first group receive no parental care and may drift with water currents or congregate in still water nursery areas.

The second type of spawning behavior is that characteristic of members of the catfish and sunfish families. Members of this group have more specific habitat requirements than those of the previous group. After selection of a spawning site with suitable environmental characteristics, one or both parents construct a nest which varies in sophistication with species. The female deposits demersal, usually adhesive, eggs in the nest and the male fertilizes them. Following fertilization,

C. Evaluation of Thermal Effects on the Fish Community

Fish inhabiting the Wateree River near Wateree Station are subjected to three general areas of temperature distribution. The area of ambient water temperature from the thermal discharge upstream to Wateree Dam includes approximately 66 river miles or 87% of the area of the river. The area under most direct thermal influence of Wateree Station discharge covers a maximum of 0.5 river miles or 0.7% of the river. The area after mixing of discharge and ambient water downstream to the confluence with the Congaree River covers approximately 10 river miles or 13% of the river area.

During normal years, water temperatures within the ambient area range from 5.0°C (41.0°F) to 30.5°C (86.9°F) (Chapter IV, Table 5). Extreme ambient temperatures that have been recorded are 3.5°C (38.3°F) and 33.5°C (92.3°F), both recorded by the USGS in 1971, and not recognized in data summaries following this year (USGS, 1972, 1973, 1974, 1975 and 1976). Extremes of 5.0°C (41.0°F) and 30.5°C (86.9°F) are believed to be more reliable estimates of actual ambient temperature ranges. During 1976, weekly average ambient (condenser inlet) water temperatures ranged from 7.3°C (45.1°F) during the winter to 29.2°C (84.6°F) in the summer (Table 22). In the immediate thermal discharge area, 1976 weekly average temperatures varied from 17.0°C (62.6°F) in the winter quarter to 34.9°C (102.9°F) in the summer. Differences between weekly average intake and discharge temperatures ranged from 3.0°C (5.4°F) to 12.9°C (23.2°F). Within the area of mixed ambient and

Table 22. Seasonal minimum and maximum weekly average temperatures and Δ T (°C) at Wateree Station. (Data taken from plant operating data for 1976).

Monitoring Point	Winter (Jan-Mar)	Spring (Apr-Jun)	Summer (Jul-Sep)	Fall (Oct-Dec)
Condenser Inlet				
Temperature	7.3-15.9	16.6-26.4	25.2-29.2	8.4-23.8
Discharge Canal				
Temperature	17.0-26.3	26.8-35.3	29.1-39.4	19.9-34.1 a/
ΔT	7.1-12.9	5.4-11.7	3.0-10.8	
After Mixing b/				
Temperature	8.3-17.9	18.2-28.0	26.2-31.3	12.6-24.8 a/
ΔT	0.3-2.3	1.1-2.4	0.1-3.1	0.3-3.1

a/ Includes October and November data only.

b/ Approximately 0.8 miles downstream from discharge.

discharge water, weekly average temperatures ranged from 8.3°C (46.9°F) to 31.3°C (88.3°F). Differences between mixed water weekly averages and ambient temperatures were only 0.1°C (0.2°F) to 3.1°C (5.6°F). The thermal environments of the ambient and mixed water areas were similar during 1976.

The fish community of the Wateree River is also subjected to pronounced and frequent variations in water level (Table 3). These water level fluctuations, due to variable discharge from Wateree Dam upstream, may be as much as 10.96 feet weekly and 6.99 feet daily. Average weekly fluctuations range from 3.45 to 7.05 feet. These changes in water level undoubtedly have a pronounced impact on the fish community and are probably the most important environmental factor controlling community composition and abundance. The amount of available habitat is directly proportional to water level.

During the present study, species composition was similar among ambient, discharge and mixed water areas (Table 14). Any species that was not collected from all three areas constituted a very small percentage ($\leq$ 1.4) of total collections. No species listed as rare or endangered were observed in the study area (50 C.F.R. Part 17, October 27, 1976). Numbers of species were 25 at both ambient and discharge locations and 27 at the mixed water location. Shannon-Weaver species diversity index values were highest in the discharge area for rotenone collections, electrofishing collections and combined collections (Table 18). These data indicate no reduction in community diversity due to operation of

Wateree Station. In a similar study, Miller and DeMont (1974) found no significant difference in diversity index values between heated and unheated waters near an electric generating station in North Carolina.

Relative abundances of Wateree River sport fish species were higher in the thermal discharge and thermally mixed areas than in ambient temperature areas (Table 14). Forage fish constituted the most abundant group in all areas and preferred ambient and mixed temperature areas to the thermal discharge area. Rough fish, the least abundant group in all three areas, were most numerous in the discharge area.

Many fish species preferred areas other than the immediate thermal discharge location during the warmer months (Table 16). However, high catch rates and large numbers of species in the downstream area of mixed ambient and discharge water indicate that any influence of the thermal discharge on composition and abundance of the fish community occurred in only a small portion of the river. During the warmer period (June through September) sampling dates, water temperatures were 25.0°C (77.0°F) to 28.5°C (83.3°F) in the ambient area, 27.8°C (82.0°F) to 39.0°C (102.2°F) in the discharge area and 25.0°C (77.0°F) to 30.0°C (86.0°F) in the mixed water area (Table 15). Temperature preference and tolerance levels of three important Wateree River sport species (channel catfish, bluegill and largemouth bass) are listed in Table 23. Discharge area warm period temperatures were occasionally higher than the preferred and upper lethal temperatures for these species. Temperatures at ambient and mixed water locations were below these preferred and lethal limit

Table 23. Temperature preference and tolerance information (°C) for three important Wateree River fish species. (Data taken from USEPA, 1973)

Species	Preferred Temperature	Temperature Tolerance		
		Acclimation	Upper Limit	Lower Limit
Channel catfish	No data	15.0	30.4	0.0
		25.0	35.5	0.0
		30.0	37.0	0.0
		35.0	38.0	No data
Bluegill	32.3	15.0	30.5	2.5
		20.0	32.0	5.0
		25.0	33.0	7.5
		30.0	33.8	11.0
		32.9	37.3	15.3
Largemouth bass	30.0-32.2	20.0	32.5	5.2
		25.0	34.5	7.0
		30.0	36.4	10.5
		35.0	36.4	No data

levels. Also, only in the immediate discharge area were summer temperatures above USEPA (1976) recommended short term limits for summer survival of juvenile and adult channel catfish, bluegill and largemouth bass (Table 24).

Fish, being very mobile organisms, tend to locate in areas of preferred water temperature and avoid areas of lethal or detrimental temperatures. Neill and Magnuson (1974) found that fish, in a lake receiving a thermal effluent of 35.0°C (95.0°F) when ambient temperatures were 29.0°C (84.2°F), distributed themselves in the outfall area according to their temperature preferenda. Some species avoided the outfall area while others concentrated there, depending on temperature preference of individual species. Neill and Magnuson (1974) also reported that fish body temperatures and preferred temperatures agreed closely. Spigarelli, et al. (1974) found that fish collected from artificially heated water had body temperatures lower than that of the surrounding water which implied recent entry or regulation by movement between cool and warm areas. Benda and Proffitt (1974) observed fish attracted to a heated water discharge during colder months and repelled during warmer months. Wateree River fish can be expected to avoid possible lethal or detrimental temperatures in the immediate area of discharge during warmer months by moving to areas of more desirable temperature. Also, high water velocities in the discharge canal probably function in keeping fish out of highest temperature water for extended periods, since fish would have to expend a great deal of energy to

Table 24. USEPA (1976) recommended thermal requirements of three important Wateree River fish species.

Species	Maximum Weekly Average Temperature (°C) For: Growth	Maximum Weekly Average Temperature (°C) For: Spawning	Short-Term Maximum Temperature (°C) For: Adult and Juvenile Survival (Summer)	Short-Term Maximum Temperature (°C) For: Embryo Survival
Channel catfish	32.0	27.0	35.0	29.0
Bluegill	32.0	25.0	35.0	34.0
Largemouth bass	32.0	21.0	34.0	27.0

maintain themselves in this area. Because the area where potentially damaging high temperatures occur is small, movement of fish to avoid this area has no overall impact on fish distribution in the river as a whole.

During the cold weather months (November through February) sport and rough fish species preferred the Wateree Station discharge area to non-discharge areas (Table 17). Forage fish preferred non-discharge areas. Several species were attracted to the discharge area during cold months when discharge water temperatures more closely approximated those preferred by fish than did ambient temperatures. At the times of cold weather sampling, ambient area temperatures were 3.5°C (38.3°F) to 13.5°C (56.3°F), those in the discharge area were 5.0°C (41.0°F) to 25.0°C (77.0°F) and mixed temperatures were 4.0°C (39.2°F) to 14.0°C (57.2°F) (Table 15).

Attraction of fish to heated areas during colder months may result in mortality from "cold shock" if fish attempt to return to ambient temperatures or the artificial heating suddenly ceases (USEPA, 1973). A graph indicating maximum permissible weekly average discharge plume temperatures to avoid "cold shock" at various ambient temperatures was proposed by USEPA (1976) and is presented in Figure 24. During the colder months of 1976 when ambient temperatures were lowest, Wateree Station weekly average discharge temperatures did not exceed maximum limits indicated by the graph (Figure 24). No evidence of "cold shock" has been observed at Wateree Station and no mortality is expected.

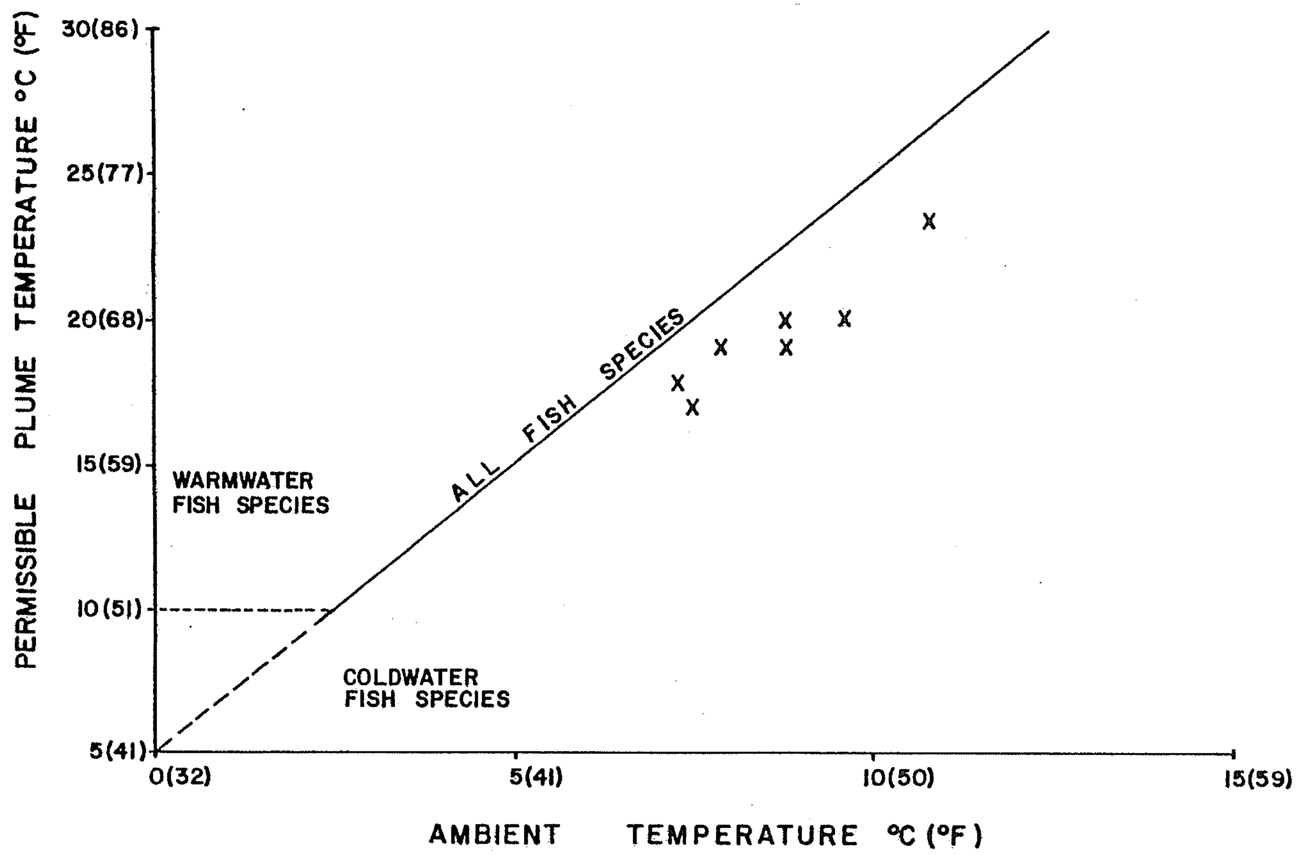

FIGURE 24

USEPA (1976) GRAPH TO ESTIMATE MAXIMUM WEEKLY AVERAGE TEMPERATURE OF PLUMES FOR VARIOUS AMBIENT TEMPERATURES °C (°F). INCLUDED ARE ACTUAL DATA POINTS (X) FROM 1976 (WINTER) WATEREE STATION PLANT OPERATING DATA.

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(A)

Possible thermal effects of operation of Wateree Station on fish community composition and abundance are limited to a very small area, with no overall impact on the river as a whole. Some species are seasonally attracted to or repelled from the immediate discharge area. Fish are able to avoid lethal or damaging temperatures they may encounter.

Statistical comparison of coefficient of fish body condition indicated little if any difference among ambient, discharge and mixed temperature areas (Table 19). Bennett and Gibbons (1974) reported that juvenile largemouth bass growth and body condition were not impaired by a thermal effluent in South Carolina. It was suggested that heated water discharges create a longer growing season for fish in the area. Benda and Proffitt (1974) found that a heated effluent did not affect growth of several sunfish species. Neill and Magnuson (1974) reported any differences in growth rate of fish between heated and unheated areas were obscured by size-dependent movements of fish. USEPA (1976) recommended maximum weekly average temperature for growth of channel catfish, bluegill and largemouth bass is 32.0°C (89.6°F) (Table 24). Weekly average Wateree River temperatures during the 1976 growing season (March through November) were below 32.0°C (89.6°F) except in the immediate thermal discharge area (Table 25). No evidence was obtained to indicate the thermal effluent had any impact on growth and body condition of area fishes.

Table 25. Water temperatures (°C) near Wateree Station during USEPA (1976) designated fish growing and spawning seasons. (Temperatures derived from plant operating data for 1976).

Monitoring Point	Growing Season (Mar-Nov)		Spawning Season (Mar-May)	
	Maximum Weekly Average	Maximum Daily Average	Maximum Weekly Average	Maximum Daily Average
Condenser Inlet (Ambient)	29.2	29.5	21.9	22.8
Discharge Canal	39.4	42.2	30.6	36.1
After Mixing a/	31.3	33.3	24.3	25.0

a/ Approximately 0.8 miles downstream of discharge.

The Wateree Station thermal discharge had no apparent effect on intensity or frequency of occurrence of external parasites and diseases (Table 20). Incidences of parasitic infestations were low in both heated and unheated areas. Similar types of parasites occurred in all areas. Water temperatures suitable for development of parasites occurred in both ambient and thermally influenced areas.

The Wateree Station discharge did not hinder successful reproduction of fishes. Collection of a variety of size groups of the more abundant sport species indicates that successful reproduction occurred over the past several years in both heated and unheated areas (Figure 25). Young-of-the-year individuals of many species were collected. Flathead catfish were introduced into the Wateree River in 1964 (Joe Logan, South Carolina Wildlife and Marine Resources Department, Personal Communication, February 1977) and the collection of young fish in the vicinity of Wateree Station demonstrates that this sport species is reproducing in the area. USEPA (1976) recommended maximum weekly average temperatures for development during the spawning season are 27.0°C (80.6°F) for channel catfish, 25.0°C (77.0°F) for bluegill and 21.0°C ((69.8°F) for largemouth bass (Table 24). Temperatures recorded during the 1976 spawning season were within recommended limits for channel catfish and bluegill in the ambient and thermally mixed areas (Table 25). Temperatures in both heated and unheated areas were above those recommended for largemouth bass; however, fish collection data indicated that this species was reproducing successfully (Figure 25). Temperatures in the

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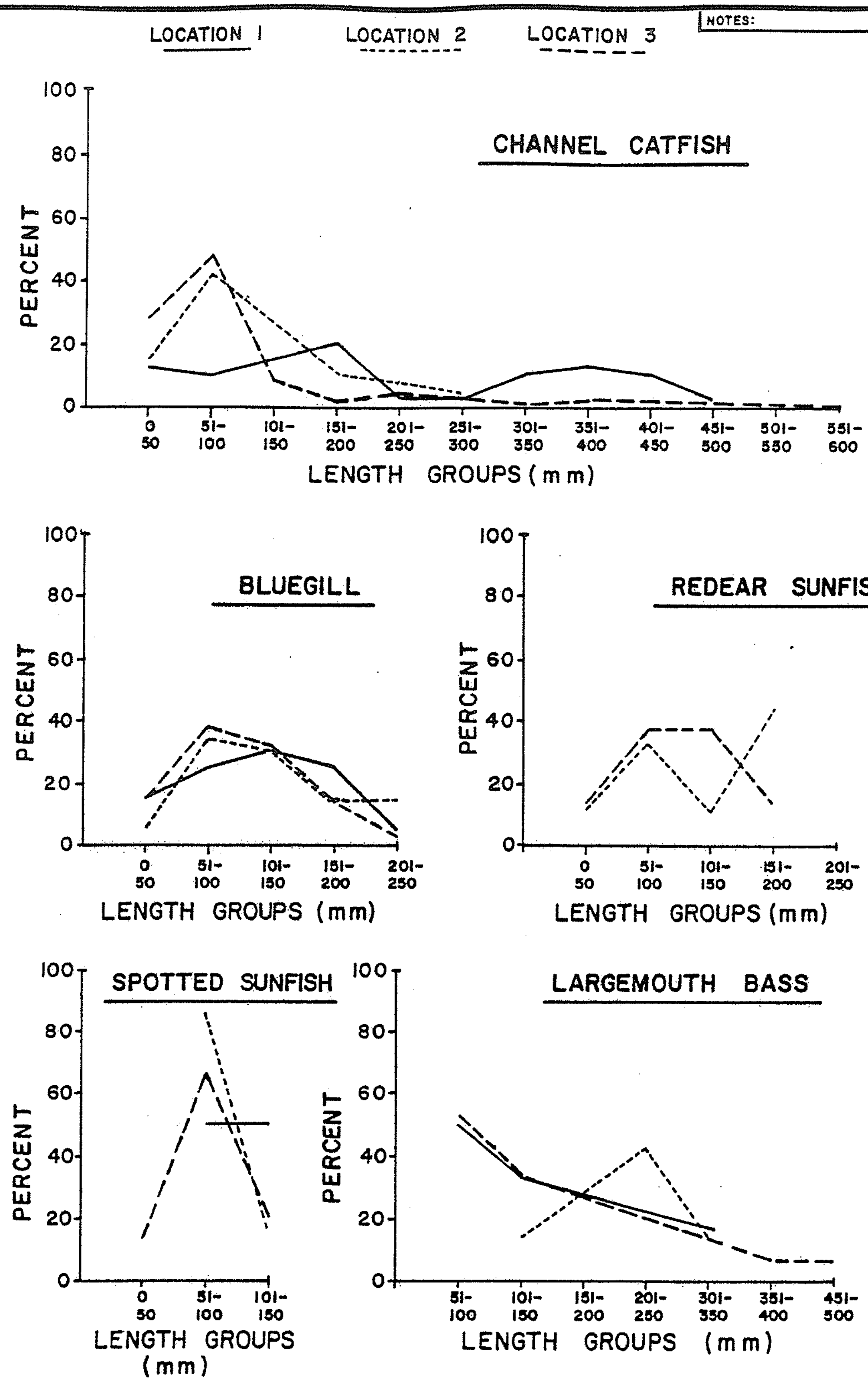

REV.	DATE	BY	DESCRIPTION	APP.
			REVISION	

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FIGURE 25

LENGTH COMPOSITION OF FIVE FISH SPECIES COLLECTED NEAR WATEREE STATION DURING JUNE 1976 THROUGH FEBRUARY 1977.

ENGINEERING REPROGRAPHICS 84272 PC4-2 5-74.

(A)

immediate discharge area were above those recommended for spawning of all three species; however, this area was very small. USEPA (1976) recommended short-term maximums for survival of channel catfish, bluegill and largemouth bass embryos are 29.0°C (84.2°F), 34.0°C (93.2°F) and 27.0°C (80.6°F), respectively (Table 24). Maximum daily average temperatures were lower than these recommended limits in the ambient and mixed areas but not the immediate discharge area (Table 25). In general, only a small area of the river in the immediate vicinity of the Wateree Station discharge is thermally unacceptable for reproduction by channel catfish, bluegill and largemouth bass, according to USEPA proposed criteria. However, small individuals of all these species were observed in the immediate discharge area indicating that reproduction had occurred.

It is doubtful that the Wateree Station thermal plume represents a block to the upstream migration of fish. The only species in the area that migrate long distances to spawn are the hickory shad, white and striped bass. Both hickory shad and white bass were observed upstream of the Station, indicating that there was no block to their migration. Striped bass were collected only during the colder months and exhibited a strong attraction to the thermal discharge area. Obviously, the thermal plume was not a block to migration in terms of heated water repelling these fish, and it is doubtful that their attraction to the discharge prevented their continued movement upstream. The collection of progressively fewer striped bass in the discharge area after December (Table 17) may indicate that these fish migrated upstream. Scruggs

(1955) and May and Fuller (1962) have demonstrated that the Wateree River is not an important spawning ground for striped bass, therefore few fish are expected to migrate through the area. Benda and Proffitt (1974) found that a thermal plume extending across the White River in Indiana did not create a barrier to migrating fish. Wrenn (1976) reported that thermal effluent temperatures of 33.0-35.0°C were not a barrier to movement of flathead catfish and largemouth bass.

Fluctuating water levels in the Wateree River probably represent the greatest hazard to fish reproduction. Fluctuations as large as 10.96 feet per week and 6.99 feet per day occur. Decreasing water levels during the spawning season would result in the loss of demersal, adhesive eggs deposited in the water that is less than the depth of the fluctuation. Also, low water levels greatly reduce the area of adjacent swamps and tributary streams that provide suitable spawning and nursery habitat for many species.

D. Entrainment of Fish Eggs and Larvae

The most important potential impact of condenser cooling system and thermal plume entrainment on aquatic organisms at Wateree Station is the possible loss of striped bass eggs and larvae. The eggs and larval stages of this species characteristically drift with river currents (Table 21) and are therefore vulnerable to entrainment. Other important species, such as members of the sunfish and catfish families, have adhesive, demersal eggs and larval stages that remain in a nest-like structure and are frequently guarded by one of the parents after hatching (Table 21). Since the eggs and larvae of these species do not normally drift with water currents, they are not subject to entrainment in significant numbers.

The Wateree and Congaree Rivers are the spawning grounds of a unique landlocked striped bass population which inhabits Lakes Marion and Moultrie (Santee-Cooper Reservoir). This population supports a substantial sport fishery and is of considerable economic importance. Two studies have been conducted between 1955 and 1962 to evaluate striped bass spawning activities in the Wateree and Congaree Rivers. Results of these studies adequately describe the presence and abundance of striped bass eggs and larvae in the two rivers. These data are utilized to assess the impact of entrainment of these organisms at Wateree Station.

Scruggs (1955) sampled striped bass eggs and larvae with one meter diameter plankton nets below the US 601 bridge on the Congaree River and on the Wateree River approximately 200 yards upstream from its confluence with the Congaree (Figure 1). Striped bass eggs were collected from the Congaree River between April 8 and June 2 with peak abundance on April 21. On the Wateree River eggs were observed from April 21 through May 19 and were most abundant on May 5. Maximum abundances were 83.40 eggs per minute of sampling on the Congaree River and only 3.53 eggs per minute of sampling on the Wateree River. These data indicate that the Congaree River was a more important spawning ground than the Wateree River.

An intensive study of striped bass spawning in the Wateree and Congaree Rivers was conducted by the South Carolina Wildlife Resources Department and reported by May and Fuller (1962). Egg samples were collected with 20 inch diameter plankton nets at three hour intervals throughout the spawning seasons of 1961 and 1962. The following conclusions are quoted from the May and Fuller report.

> It is obvious from the 1961 and 1962 population estimates for striped bass eggs made on the Congaree and Wateree Rivers that the Congaree River is supporting the bulk of striped bass spawning for the Santee-Cooper Reservoir. (page 219)
>
> In 1961 the number of eggs spawned in the Congaree River made up approximately 96 percent of all eggs which were carried down to the upper reaches of the Santee-Cooper Reservoir. The same was true in 1962 when the eggs spawned in the Congaree River made up approximately 95 percent of all eggs going into the reservoir. (page 291)
>
> The 1961-1962 study indicated that only 5 percent or less of the potential recruitment of the reservoir striped bass fishery occured in the Wateree River. (page 300)
>
> It is doubtful if the loss of the eggs spawned in the Wateree River would appreciably affect the striped bass population in the reservoir.... (page 296)

It is apparent from the results of these studies that condenser cooling system and thermal plume entrainment of striped bass eggs and larvae at Wateree Station has little, if any, impact on the adult fish population. The Wateree River is not an important spawning ground for striped bass, therefore, few eggs and larvae occur in the river and even fewer are actually entrained.

E. Impingement of Juvenile and Adult Fish

1. Description of the Intake Structure

The intake structure at Wateree Station consists of four circulating water pumps (85,000 GPM capacity per pump), two traveling screens (3/8 inch mesh) for each pump and stationary vertical bar screens (Chapter III, Figures 3 and 4). Intake pumps and screens are located at the end of a canal which is separated from the Wateree River by a dike. Cooling water passes through the dike via six 72 inch diameter conduits. Water is pumped from the canal, through the vertical bar screens and traveling screens to the condenser cooling system.

Vertical bar screens remove large items of debris from the cooling water. Smaller pieces of debris and impinged organisms are collected on the traveling screens. During normal washing operations, rotation of the traveling screens is activated by pressure differential across the screens, so that washing occurs whenever there is sufficient build-up of debris or organisms. The collected material is washed from the screens by water jets and is carried via a sluiceway to a catch basin.

2. Monitoring Procedure

Organisms impinged on traveling screens were monitored twice per month from January 1975 through March 1976. Weekly monitoring was conducted during January 1976 to evaluate heavy impingement of threadfin shad more closely.

Traveling screens were rotated and washed 24 hours prior to each monitoring. During the 24 hour period, normal washing operations were continued, however, all material washed from the screens was collected in a 3/8 inch mesh wire basket before it entered the catch basin. The trash basket was emptied as often as necessary during the 24 hour period, and collected organisms retained. At the end of the 24 hour period, screens were again rotated and washed. All collected organisms were counted and identified to the lowest positive taxonomic level. Total weight and size distribution were recorded for each fish taxon. When large numbers of threadfin shad were collected, total numbers were estimated from a counted and weighed subsample. General physical condition of collected fish was recorded. The number of pumps in operation and intake water temperature were noted at the time of monitoring.

3. Results and Discussion

Impingement monitoring between January 1975 and March 1976 resulted in the collection of 264,788 fish representing 20 taxonomic groups (15 species and five genera) (Table 26). Threadfin shad made up 99.9% of the total number and 97.8% of the total weight collected. Gizzard shad, catfishes and yellow perch were most numerous of the remaining taxa. Impingement rates of important sport species, such as the striped bass and members of the sunfish family, were very low. The

Table 26. Abundance and biomass of organisms collected for Wateree Station intake sereens, January 1975 through March 1976.

Organisms Collected	Total Number Collected	Percent of Total Number (fish only)	Total Weight Collected (g) (fish only	Percent of Total Weight (fish only)
Bowfin	1	0.4	30.0	0.2
American eel	1	0.4	1420.0	11.1
Herring (*Alosa* sp.)	2	0.8	71.0	0.6
Shad (*Dorosoma* sp.)	9	3.6	457.0	3.6
Gizzard shad	48	19.3	974.0	7.6
Threadfin shad	264,539	99.9 a/	574,178.0	97.8 a/
Redfin pickerel	4	1.6	146.0	1.1
Carp	3	1.2	1375.0	10.7
Catfish (*Ictalurus* sp.)	26	10.4	1114.0	8.7
White catfish	8	3.2	432.0	3.4
Channel catfish	62	24.9	1821.0	14.2
Pirate perch	2	0.8	10.0	0.1
Striped bass	3	1.2	3380.0	26.4
Sunfish (*Lepomis* sp.)	5	2.0	118.0	0.9
Flier	2	0.8	70.0	0.5
Warmouth	1	0.4	21.0	0.2
Redear sunfish	6	2.4	62.0	0.5
White crappie	1	0.4	61.0	0.5
Darter (*Etheostoma* sp.)	1	0.4	4.0	<0.1
Yellow perch	64	25.7	1250.0	9.8
Total fish	264,788		586,994.0	
Tadpole	1	-	-	-
Siren	1	-	-	-
Crayfish	1	-	-	-
Asiatic clam	660	-	-	-

a/ This percent includes all fish, others exclude the threadfin shad.

Asiatic clam was the most numerous non-fish organism. A complete tabulation of impingement monitoring data is presented in Appendix C, Table 1.

A field survey of the local fish community conducted during June 1976 through February 1977 resulted in the collection of a greater diversity of fishes than did impingement monitoring (Table 27). Relative abundances of species were also different between the two studies. Twenty-three species collected during the field survey were not observed in impingement collections, while six species were limited to impingement samples. Threadfin shad dominated impingement collections but made up less than 5% of field collections. Whitefin shiners and coastal shiners were the most abundant species in the field survey but were not observed in impingement trash basket samples. Catfish, especially the channel catfish, were numerous in both studies. Sunfishes (including the redbreast sunfish, green sunfish, pumpkinseed, warmouth, bluegill, redear sunfish, spotted sunfish and largemouth bass) were much more abundant in field survey samples than impingement samples. The yellow perch made up a larger percent of impingement collections than field collections. In general, fish species were not impinged in the same proportions as they occurred in the river.

Impingement rates were highest during the months of December, January, February and March and were a reflection of numbers of threadfin shad collected (Table 28). Other fish species were impinged in largest numbers during March, April and May. Few fish other than threadfin shad were impinged during the July through January period, and threadfin shad

Table 27. Relative abundances of fish impinged on Wateree Station intake screens during January 1975 through March 1976, and of those collected in a field survey of the local fish community conducted during June 1976 through February 1977.

Species	Percent Composition [a/] Screen Impingement	Field Collection
Longnose gar	-	3.7
Bowfin	0.4	0.1
American eel	0.4	-
Herring (Alosa sp.)	0.8	-
Hickory shad	-	0.2
Shad (Dorosoma sp.)	3.6	-
Gizzard shad	19.3	6.7
Threadfin shad	99.9	4.3
Redfin pickerel	1.6	-
Chain pickerel	-	0.1
Carp	1.2	1.6
Silvery minnow	-	9.2
Golden shiner	-	0.2
Shiner (Notropis sp.)	-	0.8
Taillight shiner	-	1.4
Whitefin shiner	-	17.8
Coastal shiner	-	30.3
Spotted sucker	-	1.0
Catfish (Ictalurus sp.)	10.4	-
White catfish	3.2	0.1
Blue catfish	-	0.1
Yellow bullhead	-	0.1
Brown bullhead	-	0.2
Channel catfish	24.9	7.3
Flathead catfish	-	0.8
Mosquitofish	-	0.4
Pirate perch	0.8	-
White bass	-	0.8
Striped bass	1.2	1.0
Flier	0.8	-
Sunfish (Lepomis sp.)	2.0	5.3
Redbreast sunfish	-	0.5
Green sunfish	-	0.1
Pumpkinseed	-	1.2
Warmouth	0.4	1.0
Bluegill	-	3.6
Dollar sunfish	-	0.1
Redear sunfish	2.4	0.9
Spotted sunfish	-	1.8
Largemouth bass	-	1.4
White crappie	0.4	-

Table 27. (Continued)

Species	Percent Composition[a/] Screen Impingement	Field Collection
Black crappie	-	0.3
Darter (*Etheostoma* sp.)	0.4	-
Swamp darter	-	0.1
Tessellated darter	-	0.2
Yellow perch	25.7	0.2
Striped mullet	-	0.1

a/ Percent for threadfin shad includes all fish, percents for others exclude numbers of threadfin shad.

Table 28. Monthly mean numbers of organisms collected from Wateree Station intake screens, January 1975 through March 1976.

Organisms Collected	Jan 1975	Feb 1975	Mar 1975	Apr 1975	May 1975	Jun 1975	Jul 1975	Aug 1975	Sep 1975	Oct 1975	Nov 1975	Dec 1975	Jan 1976	Feb 1976	Mar 1976
Bowfin	-	-	-	-	0.5	-	-	-	-	-	-	-	-	-	-
American eel	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-
Herring (Alosa sp.)	-	-	-	1.0	-	-	-	-	-	-	-	-	-	-	-
Shad (Dorosoma sp.)	-	-	-	4.0	-	0.5	-	-	-	-	-	-	-	-	-
Gizzard shad	-	-	-	22.5	1.0	0.5	-	-	-	-	-	-	-	-	-
Threadfin shad	45165.0	43147.5	8138.5	-	-	-	-	2.5	3.5	2.7	196.5	6030.0	13724.3	2077.5	56.0
Redfin pickerel	1.0	1.0	-	-	-	-	-	-	-	-	-	-	-	-	-
Carp	-	-	-	-	-	0.5	-	1.0	-	-	-	-	-	-	-
Catfish (Ictalurus sp.)	-	0.5	3.0	7.5	1.0	1.0	-	-	-	-	-	-	-	-	-
White catfish	-	-	-	0.5	-	-	-	1.5	1.0	0.3	-	-	-	-	0.5
Channel catfish	-	0.5	-	15.0	11.5	3.0	1.0	-	-	-	-	-	-	-	-
Pirate perch	-	-	1.0	-	-	-	-	-	-	-	-	-	-	-	-
Striped bass	-	-	-	-	1.0	-	0.5	-	-	-	-	-	-	-	-
Sunfish (Lepomis sp.)	-	-	0.5	1.5	-	0.5	-	-	-	-	-	-	-	-	-
Flier	-	-	-	0.5	0.5	-	-	-	-	-	-	-	-	-	-
Warmouth	-	0.5	-	-	-	-	-	-	-	-	-	-	-	-	-
Redear sunfish	-	-	-	2.5	0.5	-	-	-	-	-	-	-	-	-	-
White crappie	-	-	-	-	0.5	-	-	-	-	-	-	-	-	-	-
Darter (Etheostoma sp.)	-	-	0.5	-	-	-	-	-	-	-	-	-	-	-	-
Yellow perch	-	2.5	23.0	4.0	-	-	-	-	-	-	-	-	-	-	2.5
Total fish	45166.0	43152.5	8166.5	58.5	16.5	6.0	1.5	5.0	4.5	3.0	196.5	6030.0	13724.6	2077.5	59.0
Tadpole	-	-	-	0.5	-	-	-	-	-	-	-	-	-	-	-
Siren	-	-	-	-	0.5	-	-	-	-	-	-	-	-	-	-
Crayfish	-	-	0.5	-	-	-	-	-	-	-	-	-	-	-	-
Asiatic clam	-	-	6.0	42.5	35.0	49.0	15.0	47.0	15.0	60.0	10.0	-	-	-	20.0

were not observed during April through July. Heavy impingement of threadfin shad during the winter months resulted from naturally occurring die-offs associated with low temperatures and will be discussed later. Impingement of other species during the spring months may have been related to increased movements due to spawning activities.

Impingement rates had little relationship with volume of cooling water flow (Table 29). On many occasions, few or no fish were impinged when the Station was operating at full capacity. Volume of water flow and water level determine intake velocity. Edwards, et al., (1976) reported that impingement rates at four generating stations in North and South Carolina could not be explained on the basis of intake velocity. This is apparently the case at Wateree Station also.

Fish impingement, especially that of threadfin shad, was closely related to water temperature (Table 29). When temperatures were below 10-13°C (50-55°F), large numbers of threadfin shad were impinged. This relationship has been reported for other Carolina (Edwards, et al., 1976) and TVA (Griffith and Tomljanovich, 1975) generating stations. Threadfin shad mortalities have been associated with low water temperatures by Strawn (1963) and Kimsey and Parsons (1954). Edwards, et al. (1976) found that threadfin shad became stressed and susceptible to impingement at temperatures below 13°C (55°F). Results of impingement monitoring at Wateree Station closely agree with these findings. Threadfin shad impingement during the winter months appears to be a result of stress and mortality due to low temperatures rather than a cause of

Table 29. Water temperature, cooling water flow rate and numbers of fish collected from Wateree Station intake screens, January 1975 through March 1976.

Sampling Date	Intake Temp (°C)	Cooling Water Flow (% of Capacity)	Numbers of Threadfin shad Collected	Numbers of Other Species Collected
7-8 Jan 1975	10.0	100	82,830	-
23-24 Jan 1975	10.6	59	7500	2
6-7 Feb 1975	10.6	100	22,521	1
17-18 Feb 1975	12.7	75	63,774	9
5-6 Mar 1975	-	50	15,003	1
20-21 Mar 1975	14.4	100	1274	55
16-17 Apr 1975	15.6	100	-	49
30 Apr-1 May 1975	21.1	100	-	69
13-14 May 1975	21.7	100	-	13
28-29 May 1975	26.1	100	-	20
9-10 Jun 1975	27.2	100	-	3
26-27 Jun 1975	26.7	100	-	9
7-8 Jul 1975	26.7	64	-	1
23-24 Jul 1975	27.2	100	-	2
4-5 Aug 1975	28.3	100	-	1
20-21 Aug 1975	30.0	100	5	4
4-5 Sep 1975	28.9	100	7	2
17-18 Sep 1975	23.3	50	-	-
2-3 Oct 1975	23.9	50	3	1
15-16 Oct 1975	21.7	50	5	-
30-31 Oct 1975	21.1	100	-	-
11-12 Nov 1975	21.7	100	18	-
24-25 Nov 1975	13.9	50	375	-
10-11 Dec 1975	12.8	100	-	-
22-23 Dec 1975	8.9	100	12,060	-
7-8 Jan 1976	8.3	100	14,820	-
12-13 Jan 1976	6.7	100	7927	-
22-23 Jan 1976	6.7	100	23,650	-
27-28 Jan 1976	6.7	100	8500	1
5-6 Feb 1976	8.9	50	1620	-
17-18 Feb 1976	11.7	100	2535	-
3-4 Mar 1976	13.9	50	98	-
17-18 Mar 1976	13.3	50	14	6

mortality. Thermal discharges from electric generating stations have been credited with perpetuating threadfin shad populations during winter months in North Carolina waters where they would otherwise not survive (McNaughton, 1966).

Most impinged fish were small individuals (Appendix C, Table 1). Threadfin shad ranged up to 152 mm in total length, but most were less than 100 mm. The majority of gizzard shad were also less than 100 mm in length, and the largest individual was 279 mm. Members of the catfish family were usually less than 200 mm. Yellow perch ranged from 77 to 216 mm in length, but averaged less than 150 mm. Sunfishes were 38 to 140 mm long but few were more than 100 mm. The largest fish impinged was a 762 mm American eel. The three striped bass collected were 254, 419 and 451 mm in total length.

The physical condition of impinged fish ranged from alive and apparently healthy to dead and decomposed. Nearly all fish were dead when examined at the end of the 24 hour monitoring period. Although it was not possible to determine how many individuals were dead or injured prior to impingement, it is probable that a large percent were in this condition.

Information obtained during January through December 1975 was used to estimate an annual impingement rate at Wateree Station of approximately 3,000,000 fish (Table 30). When threadfin shad are excluded, the annual rate is only 3663 fish. It is likely that many of these fish are injured or dead prior to impingement, and that mortality due to

Table 30. Estimated annual total numbers and weights of fish impinged on Wateree Station intake screens. Estimates are based on 576 sampling hours during January through December 1976.

Fish Collected	Total Number Collected	Estimated Annual Number	Weight Collected (g)	Estimated Annual Weight (g)
Bowfin	1	15	30.0	456
Herring (Alosa sp.)	2	30	71.0	1079
Shad (Dorosoma sp.)	9	137	457.0	6946
Gizzard shad	48	730	974.0	14,804
Threadfin shad	205,375	3,121,700	396,428.0	6,025,706
Redfin pickerel	4	61	146.0	2219
Carp	3	46	1375.0	20,900
Catfish (Ictalurus sp.)	26	395	1114.0	16,933
White catfish	7	106	388.0	5898
Channel catfish	62	942	1821.0	27,679
Pirate perch	2	30	10.0	152
Striped bass	3	46	3380.0	51,376
Sunfish	5	76	118.0	1794
Flier	2	30	70.0	1064
Warmouth	1	15	21.0	319
Redear sunfish	6	91	62.0	942
White crappie	1	15	61.0	927
Darter (Etheostoma sp.)	1	15	4.0	61
Yellow perch	59	897	1212.0	18,422
Total fish	205,616	3,125,363	407,742.0	6,197,678

impingement is low. Based on the species composition, relative abundance of species and total number of individuals collected during the investigation, it is doubtful that impingement at Wateree Station has any significant impact on the fish community of the river.

F. Summary

A study of the fish community of the Wateree River near Wateree Station was conducted during June 1976 through February 1977. Intake screen impingement of aquatic organisms was monitored during January 1975 through March 1976. Information obtained in these investigations and from the published literature indicate that operation of Wateree Station has not caused prior appreciable harm to the indigenous aquatic communtiy of the river. Station operation has not resulted in significant increases in abundance of nuisance species or reduction in abundance of any valuable species.

Species composition, relative abundance of important species and diversity of the indigenous fish community are not harmfully altered by the thermal effluent. No rare or endangered fish species are know to occur in the area. Growth and body condition of important fish species are not impaired by operation of the Station. The thermal discharge does not enhance frequency of occurrence or intensity of infestation of fish parasites and diseases. Successful reproduction of important fish species is not hindered by Station operation.

The striped bass is the only major fish species in the area with pelagic eggs and larval stages that would be susceptible to condenser cooling system and thermal plume entrainment in significant numbers. It has been demonstrated by state agency studies that the Wateree River is not an important spawning area for striped bass. This information precludes the possibility of significant detrimental effects of entrainment on the fish community. Fish impinged on intake screens consist primarily of threadfin shad which have been killed or immobilized by low ambient temperatures during colder months. Impingement rates of other species are extremely low and have no effect on the indigenous community.

REFERENCES

Bailey, R. M. 1970. A list of common and scientific names of fishes from the United States and Canada. 3rd ed. Am. Fish. Soc. Spec. Publ. 6. 150 pages.

Bechtel, T. J. and B. J. Copeland. 1970. Fish species diversity indices as indicators of pollution in Galveston Bay, Texas. Contr. Mar. Sci. Univ. Tex. 15:103-132.

Benda, R. S. and M. A. Proffitt. 1974. Effects of thermal effluents on fish and invertebrates. pp. 438-447. In J. W. Gibbons and R. F. Sharitz (eds.) Thermal ecology. National Technical Information Service, Springfield, Va.

Bennett, D. H. and J. W. Gibbons. 1974. Growth and Condition of juvenile largemouth bass from a reservoir receiving thermal effluent. pp. 246-254. In J.W. Gibbons and R. R. Sharitz (eds.) Thermal ecology. National Technical Information Service, Springfield, Va.

Bodola, A. 1966. Life history of the gizzard shad, *Dorosoma cepedianum* (Lesueur), in Western Lake Erie. U. S. Fish and Wildl. Serv., Fish. Bulletin 65(2): 391-425.

Bowen, J. T. and R. E. Putz. 1968. Parasites of freshwater fishes; IV, Miscellaneous, The anchor worm (*Lernaea cyprinacea*) and related species. U. S. Dept. of Int., Bur. Sport Fish. and Wildl. Fish Disease Leaflet 12, June 1968.

Bowen, J. T. and T. E. Putz. 1968. Parasites of freshwater fish; IV, Miscellaneous, 3 Parasitic copepod *Argulus*. U. S. Dept. of Int., Bur. Sport Fish. and Wildl. Fish Disease Leaflet 3, March 1966.

Burns, J. W. 1966. Threadfin shad. pp. 481-488. In A. Calhoun (ed.) Inland fisheries management. Calif. Dept. of Fish and Game.

Chadwick, H. K., C. von Geldern, Jr. and M. Johnson. 1966. White bass. pp. 412-422. In A. Calhoun (ed.) Inland fisheries management. Calif. Dept. of Fish and Game.

Davis, H. S. 1965. Culture and diseases of game fishes. Univ. of California Press, Berkley and Los Angeles. 332 pages.

Davis, J. R. 1972. The spawning behavior, fecundity rates and food habits of the redbreast sunfish in southeastern North Carolina. Proc. 25th. Ann. Conf. S. C. Assoc. Game and Fish Comm. pp. 556-560.

Davis, J. R. and D. L. Louder. 1971. Life history and ecology of the cyprinid fish Notropis petersoni in North Carolina waters. Trans. Am. Fish Soc. 100(4):726-733.

Edwards, T. J., W. H. Hunt, L. E. Miller and J. J. Sevic. 1976. An Evaluation of the impingement of fishes at four Duke Power Company generating facilities. pp. 373-380. In G. W. Esch and R. W. McFarlane (eds.) Thermal ecology II. National Tech nical Information Service, Springfield, Va.

Emig, J. W. 1966. Bluegill sunfish. pp. 375-392. In A. Calhoun (ed.) Inland fisheries management. Calif. Dept. of Fish and Game.

Emig, J. W. 1966. Largemouth bass. pp. 332-353. In A. Calhoun (ed.) Inland fisheries management. Calif. Dept. of Fish and Game.

Emig, J. W. 1966. Redear sunfish. pp. 392-399. In A. Calhoun (ed.) Inland fisheries management. Calif. Dept. of Fish and Game.

Griffith, J. S. and D. A. Tomljanovich. 1975. Susceptibility of threadfin shad to impingement. Paper presented at Southern Division, American Fisheries Society Meeting; October 12-15, 1975.

Holloway, A. D. 1954. Notes on the life history and management of the shortnose and longnose gar in Florida waters. J. Wildl. Management. 18(4):438-449.

Hubbell, P. M. 1966. Pumpkinseed sunfish. pp. 402-404. In A. Calhoun (ed.) Inland fisheries management. Calif. Dept. of Fish and Game.

Huggins, E. J. 1972. Parasites of fishes in South Dakota. South Dakota Dept. of Game, Fish and Parks. Bulletin 484. 73 pages.

Hynes, H. B. N. 1972. The ecology of running waters. Univ. of Toronto Press. 555 pages.

Lippson, A. J. and R. L. Moran. 1974. Manual for identification of early development stages of fishes of the Potomac River Estuary. Environmental Technology Center, Martin Marietta Corporation, Baltimore, Md. 282 pages.

Lloyd, M. , J. H. Zar and J. R. Karr. 1968. On the calculation of information--theoretical measures of diversity. Am. Mid. Nat. 79(2):257-272.

Mansueti, A. J. and J. D. Hardy, Jr. 1967. Development of fishes of the Chesapeake Bay Region: An atlas of egg, larval and juvenile stages. Part I. Nat. Res. Inst. Univ. of Maryland. 202 pages.

May, O. D. Jr. and J. C. Fuller. 1962. A study on striped bass egg production in the Congaree and Wateree Rivers. Proc. 16th Ann. Conf. S. E. Assoc. Game and Fish Comm. pp. 285-301.

McNaughton, W. D. 1966. The threadfin shad in North Carolina waters. North Carolina Wildlife Resources Commisssion, D-J Proj. F-16-R, Job X-A.

Miller, E. E. 1966. Channel catfish. pp. 440-463. In A. Calhoun (ed.) Inland fisheries management. Calif. Dept. of Fish and Game.

Miller, R. W. and D. J. DeMont. 1974. Fisheries research. pp. 187-216. In L. D. Jensen (ed.) Environmental responses to thermal discharges from Marshall Steam Station, Lake Norman, North Carolina. Research Project RP-49, Report II. The Johns Hopkins University Press, Baltimore.

Neill, W. H. and J. J. Magnuson. 1974. Distributional ecology and and behavorial thermoregulation of fishes in relation to heated effluent from a power plant at Lake Monona, Wisconsin. Trans. Am. Fish Soc. 103(4):663-710.

Parsons, J. W. and J. B. Kimsey. 1954. A report on the Mississippi threadfin shad. Prog. Fish Cult. 16(4):179-181.

Pflieger, W. L. 1975. The fishes of Missouri. Missouri Dept. of Conservation. 343 pages.

Rogers, W. A. 1970. A summary of fish disease cases received over a five-year period at the Southeastern Cooperative Fish Disease Laboratory. Proc. 23rd. Ann. Proc. S. E. Assoc. Game and Fish Comm. pp. 353-358.

Rogers, W. A. 1972. Disease in fish due to the protozoan Epistylis (Ciliatae:Peritricha) in the Southeastern U. S. Proc. 25th Ann. Conf. S. E. Assoc. Game and Fish Comm. pp. 493-496.

Schetz, J. A., J. A. Payne, and B. L. Sill, 1975a. The effects of discharge design on the thermal mixing zone in waterways. Proc., Energy and the Environment, Institute of Environmental Sciences Conference, Anaheim, California.

Schetz, J. A., J. A. Payne, and B. L. Sill, 1975b. The effects of discharge design on the thermal mixing zone in waterways. 1975 International Seminar on Future Energy Production-Heat and Mass Transfer Problems, International Center for Heat and Mass Transfer, Dubrovnik, Yugoslavia.

Schetz, J. A., C. H. Lewis, B. L. Sill, J. C. Chien and D. Markham, 1976. Penetration and mixing of heated discharges into waterways. Va. Water Resources Research Center, Bulletin 93, Virginia Polytechnic Institute and State University, Blackburg, Virginia.

Scruggs, G. D. Jr. 1955. Reproduction of resident striped bass in Santee-Cooper Reservoir, South Carolina. Trans. Am. Fish Soc. 85(1):144-159.

Sill, B. L. and J. A. Schetz, 1973. Studies of a heated, turbulent jet in a shallow, bounded waterway. Rept. Aero-005, Virginia Polytechnic Institute and State University.

Sill, B. L. and J. A. Schetz, 1975a. Thermal pollution in a bounded waterway. In Thermal Pollution Analysis, Progress in Astronautics and Aeronatics, Vol. 36, M.I.T. Press, Cambridge, Mass.

Sill, B. L. and J. A. Schetz, 1975b. Use of experimental measurements in the development of a thermal effluent model. Proc., 1975 IEEE Southeastern Region 3 Conference, Vol. 1, Charlotte, North Carolina.

Spigarelli, S. A., G. P. Romberg, W. Prepejchal, and M. M. Thommes. 1974. Body-temperature characteristics of fish at a thermal discharge on Lake Michigan. pp. 119-132. In J. W. Gibbons and R. F. Sharitz (eds.) Thermal ecology. National Technical Information Service, Springfield, Va.

Stallings, J. S. 1967. South Carolina streamflow characteristics low-flow frequency and flow duration. U. S. Department of the Interior, Geological Survey. Open File Report.

Strawn, K. 1963. Resistance of threadfin shad to low temperature. Proc. 17th Ann. Conf., S. E. Assoc. Game and Fish Comm. pp. 290-293.

U. S. Enviromental Protection Agency. 1974. Development document for effluent limitations guidelines and new source performance standards for the steam electric power generating point source category. Effluent Guidelines Division, Washington, D. C.

USEPA, 1973a. Proposed criteria for water quality. Volume I. U. S. Environmental Protection Agency, Washington, D. C. 425 pages.

USEPA. 1973b. Biological field and laboratory methods for measuring the quality of surface waters and effluents. EPA-670/4-73-001. U. S. Environmental Protection Agency, Cincinnati, Ohio.

USEPA. 1974. Guide to the design of 316 demonstrations. Region IV U. S. Environmental Protection Agency, Atlanta, Georgia.

USEPA. 1976. Quality criteria for water. U. S. Environmental Protection Agency, Washington, D. C.

United States Geological Survey. 1970. Water resources for South Carolina. U. S. Department of Interior, Geological Survey.

United States Geological Survey. 1971. Water resources data for South Carolina. U. S. Department of Interior, Geological Survey.

United States Geological Survey. 1972. Water resources data for South Carolina. U. S. Department of Interior, Geological Survey.

United States Geological Survey. 1973. Water resources data for South Carolina. U. S. Department of Interior, Geological Survey.

United States Geological Survey. 1974. Water resources data for South Carolina. U. S. Department of Interior, Geological Survey.

United States Geological Survey. 1975. Water resources data for South Carolina. U. S. Department of Interior, Geological Survey.

United States Geological Survey, 1976. Water resources data for South Carolina. U. S. Department of Interior, Geological Survey. (In Press)

Wrenn, W. B. 1976. Temperature preference and movement in relation to a long, heated discharge channel. pp 191-194. In G. W. Esch and R. W. McFarlane (eds.) Thermal Ecology II. National Technical Information Service, Springfield, Virginia.

APPENDIX A

Intake Velocity Data Summary

Intake Velocity Data Summary

DATE: February 10, 1977
RIVER STAGE: 7.82 Ft. (USGS Eastover Gage)

	INTAKE VELOCITY (fps)							
Screen Number*	1	2	3	4	5	6	7	8
Minimum	0.29	0.47	0.25	0.28	0.16	0.29	0.15	0.28
Maximum	0.88	0.77	0.90	0.79	0.73	0.74	0.79	0.66
Average	0.52	0.63	0.59	0.54	0.52	0.48	0.44	0.46

Average All Screens - 0.52

DATE: February 6, 1977
RIVER STAGE: 5.10 ft. (USGS Eastover Gage)

Minimum	0.35	0.36	0.58	0.36	0.31	0.35	0.24	0.36
Maximum	1.10	1.13	1.13	1.01	0.99	0.90	0.86	0.86
Average	0.60	0.83	0.82	0.72	0.64	0.61	0.60	0.64

Average All Screens - 0.68

DATE: February 1, 1977
RIVER STAGE: 8.00 ft. (USGS Eastover Gage)

Minimum	0.21	0.41	0.30	0.25	0.34	0.20	0.20	0.26
Maximum	0.75	0.75	0.74	0.82	0.79	0.77	0.89	0.60
Average	0.44	0.58	0.53	0.54	0.56	0.52	0.44	0.45

Average All Screens - 0.51

DATE: January 24, 1977
RIVER STAGE: 13.1 ft. (USGS Eastover Gage)

Minimum	-	0.22	-	0.09	-	0.14	-	0.15
Maximum	-	0.60	-	0.59	-	0.57	-	0.52
Average	-	0.41	-	0.42	-	0.33	-	0.34

Average All Screens - 0.38

* Facing screens, numbered left to right.

(Continued)

DATE: January 17, 1977
RIVER STAGE: 15.10 ft. (USGS Eastover Gage)

INTAKE VELOCITY (fps)								
Screen Number*	1	2	3	4	5	6	7	8
Minimum	0.20	0.13	0.24	0.24	0.19	-	0.14	-
Maximum	0.56	0.54	0.54	0.56	0.52	-	0.58	-
Average	0.41	0.41	0.40	0.38	0.37	-	0.37	-

Average All Screens - 0.39

DATE: January 13, 1977
RIVER STAGE: 15.00 ft. (USGS Eastover Gage)

Minimum	-	0.15	-	0.21	-	0.17	-	0.25
Maximum	-	0.70	-	0.66	-	0.66	-	0.52
Average	-	0.40	-	0.42	-	0.40	-	0.41

Average All Screens - 0.41

DATE: August 16, 1976
RIVER STAGE: 3.75 ft. (USGS Eastover Gage)

Minimum	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.20
Maximum	0.80	0.80	1.00	1.00	1.40	1.50	1.40	1.30
Average	0.50	0.40	0.60	0.50	0.60	0.80	0.60	0.80

Average All Screens - 0.60

* Facing Screens, numbered left to right.

APPENDIX B

Fish Collection Data

Table 1 . Fish data collected at Location 1 (Upstream), Wateree Station, June 1976–February 1977.

Sampling Date (Method)	Species Collected	Total Number a/	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
29 Jun 1976 (Rotenone)	*Dorosoma cepedianum*	1			48.5	
	Alosa mediocris	1			1.8	
	Notropis niveus	1			3.9	
	Ictalurus nebulosus	1			0.9	
	Ictalurus punctatus	7	152	24.7	110.3	
			153	25.2		
			137	19.4		
			120	11.8		
			112	9.9		
			115	10.5		
			104	8.8		
26 Jul 1976 (Rotenone)	*Lepisosteus osseus*	3			166.3	
	Alosa mediocris	2			11.8	
	Dorosoma cepedianum	16			1300.0	
	Dorosoma petenense	4			6.5	
	Hyboganthus nuchalis	4			3.9	
	Notropis petersoni	21			11.6	

Table 1 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
26 Jul 1976	*Notropis maculatus*	1			0.4	
(Rotenone)						
(Continued)	*Ictalurus punctatus*	15	497	908.8	4465.7	
			442	729.7		
			427	636.1		
			382	441.6		
			341	309.8		
			329	292.0		
			361	354.3		
			313	244.5		
			318	246.6		
			284	147.2		
			167	37.0		
			161	33.6		
			151	28.2		
			150	23.7		
			151	24.3		
		(5)	<50	8.3		
	Pylodictis olivaris	1			1.8	
	Gambusia affinis	2			0.4	
	Lepomis gulosus	1			224.4	
	Lepomis macrochirus	5	101	18.6	55.5	
			88	10.4		
			86	10.4		
			70	6.5		

Table 1 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
26 Jul 1976 (Rotenone)	<u>Lepomis</u> <u>macrochirus</u>	(3)	72 <50	6.6 3.0		
	<u>Lepomis</u> <u>punctatus</u>	1	69	6.4	6.4	
	<u>Micropterus</u> <u>salmoides</u>	1	67	4.2	4.2	
	<u>Etheostoma</u> <u>fusiforme</u>	1			1.0	
23 Aug 1976 (Rotenone)	<u>Notropis</u> <u>petersoni</u>	9			1.6	
	<u>Gambusia</u> <u>affinis</u>	2			0.4	
	<u>Lepomis</u> sp.	1	<50		0.5	
	<u>Micropterus</u> <u>salmoides</u>	3	134 61 55	27.9 2.7 1.9	32.5	
20 Sep 1976 (Rotenone)	<u>Lepisosteus</u> <u>osseus</u>	1			63.1	
	<u>Dorosoma</u> <u>cepedianum</u>	7			570.0	
	<u>Dorosoma</u> <u>petenense</u>	7			28.0	
	<u>Hybognathus</u> <u>nuchalis</u>	2			2.1	
	<u>Notropis</u> sp.	15			3.1	

Table 1 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
20 Sep 1976 (Rotenone) (Continued)	*Notropis niveus*	7			2.3	
	Notropis petersoni	16			8.9	
	Ictalurus punctatus	8	412	542.0	2592.2	
			439	735.0		
			393	490.0		
			375	425.0		
			361	365.0		
			158	27.9		
			89	5.3		
			60	2.0		
	Gambusia affinis	1			0.2	
	Morone chrysops	1	122	20.1	20.1	
	Lepomis sp.	2	<50		3.3	
3 Nov 1976 (Electro-fishing)	*Lepisosteus osseus*	1			295.0	
	Dorosoma cepedianum	3			635.0	
	Cyprinus carpio	1			2120.0	
	Notropis niveus	15			7.8	
	Notropis petersoni	1			1.0	

Table 1 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
3 Nov 1976 (Electro-fishing) (Continued)	Ictalurus punctatus	3	214 100 60	75.0 10.0 2.0	87.0	
	Lepomis punctatus	1	99	17.6	17.6	Lernaea
29 Nov 1976 (Electro-fishing)	Lepisosteus osseus	1			85.0	
	Alosa mediocris	1			20.3	
	Dorosoma cepedianum	1			110.0	
	Dorosoma petenense	1			5.6	
	Cyprinus carpio	1			1795.0	
	Hybognathus nuchalis	29			85.0	Uvulifer (29)
	Notropis niveus	101			112.0	
	Notropis petersoni	78			115.1	
	Minytrema melanops	3			1355.1	
	Ictalurus punctatus	1	188	55.0	55.0	
	Lepomis auritus	2	122 95	25.0 14.6	39.6	

Table 2 . Fish data collected at Location 2 (Discharge), Wateree Station, June 1976– February 1977.

Sampling Date (Method)	Species Collected	Total Number a/	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
29 Jun 1976 (Rotenone)	*Lepisosteus osseus*	2			43.7	
	Dorosoma petenense	2			12.6	
	Notropis niveus	1			1.7	
	Ictalurus nebulosus	2			2.3	
	Ictalurus punctatus	1 (1)	132 <50	15.4 0.8	16.2	
	Morone chrysops	1	66	3.3	3.3	
	Lepomis sp.	3	≤50		1.5	
	Lepomis cyanellus	1			33.2	
	Lepomis gulosus	1			2.9	
	Lepomis macrochirus	1	70	6.0	6.0	
	Lepomis microlophus	1	88	9.5	9.5	
26 Jul 1976 (Rotenone)	*Ictalurus punctatus*	3	138 131 77	18.5 16.4 4.1	39.0	Leech
	Pylodictis olivaris	2			7.5	
	Lepomis sp.	13	<50		5.8	

Table 2 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
20 Sep 1976 (Rotenone) (Continued)	Ictalurus punctatus		112	11.7		
			89	5.7		
			70	2.8		
			70	2.8		
			64	2.2		
			59	1.7		
		(1)	<50	0.3		
	Pylodictis olivaris	6			17.7	
	Gambusia affinis	1			0.8	
	Micropterus salmoides	1	168	56.0	56.0	Uvulifer
3 Nov 1976 (Electro-fishing)	Lepisosteus osseus	22			10,880.0	
	Cyprinus carpio	4			14,120.0	
	Notropis niveus	18			13.2	
	Notropis petersoni	1			1.4	
	Ictalurus punctatus	2	296	225.0	230.5	
			87	5.5		
	Lepomis auritus	2	121	22.8	27.7	
			70	4.9		
	Lepomis gibbosus	7			14.9	

Table 2 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
3 Nov 1976 (Electro-fishing) (Continued)	Lepomis macrochirus	6	216	215.0	370.1	Lernaea
			178	120.0		Lernaea
			121	25.0		
			66	3.7		
			66	3.6		
			<50	2.8		
	Lepomis microlophus	1	192	139.0	139.0	
	Lepomis punctatus	8	103	19.8	112.4	
			106	23.7		
			95	15.9		
			92	14.1		
			88	12.4		
			77	8.9		
			82	9.8		
			76	7.8		
	Micropterus salmoides	2	222	175.0	305.0	
			210	130.0		
29 Nov 1976 (Electro-fishing)	Lepisosteus osseus	15			9505.0	
	Dorosoma cepedianum	3			1150.0	
	Dorosoma petenense	5			21.4	
	Cyprinus carpio	4			11,935.0	

Table 2 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
29 Nov 1976 (Electro-fishing) (Continued)	_Hybognathus nuchalis_	1			3.1	_Uvulifer_
	Notropis niveus	24			32.1	
	Notropis petersoni	27			33.6	
	Ictalurus punctatus	2	177	30.0	36.0	
			90	6.0		
	Morone saxatilis	5	425	995.0	8450.0	
			458	1365.0		
			617	2765.0		
			558	2275.0		
			430	1050.0		
	Lepomis gibbosus	7			21.7	
	Lepomis macrochirus	5	201	155.0	350.9	
			182	100.0		
			174	90.0		
			70	4.1		
			55	1.8		
	Micropterus salmoides	2	219	150.0	610.0	
			326	460.0		
	Perca flavescens	1			35.0	

Table 2 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
29 Nov 1976 (Electro-fishing) (Continued)	_Mugil cephalus_	1			1830.0	
29 Dec 1976 (Electro-fishing)	_Dorosoma cepedianum_	14			670.0	
	Dorosoma petenense	5			54.0	
	Cyprinus carpio	6			16,320.0	
	Hybognathus nuchalis	4			11.2	_Uvulifer_
	Notropis niveus	2			1.8	
	Notropis petersoni	1			1.0	
	Minytrema melanops	1			1115.0	
	Pylodictis olivaris	1			1975.0	
	Morone saxatilis	9	766	6917.0	25,907.0	
			426	1115.0		
			475	1595.0		
			373	965.0		
			536	2080.0		
			564	2465.0		_Epistylis_
			703	5030.0		
			606	2655.0		

Table 2 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
29 Dec 1976 (Electro-fishing) (Continued)	Morone saxatilis		616	3085.0		
	Lepomis auritus	2	139 123	48.0 37.0	85.0	
	Lepomis gibbosus	1			8.0	
	Lepomis macrochirus	3	110 62 62	24.0 7.0 6.0	37.0	
	Lepomis microlophus	3	163 162 53	77.0 77.0 2.3	156.3	
	Lepomis punctatus	3	115 96 91	33.0 21.0 17.0	71.0	
26 Jan 1977 (Electro-fishing)	Lepisosteus osseus	2			405.0	
	Dorosoma cepedianum	5			1340.0	
	Cyprinus carpio	6			16,340.0	
	Hybognathus nuchalis	4			24.1	Uvulifer (3)
	Notropis niveus	8			8.5	

Table 2 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
26 Jan 1977 (Electro-fishing) (Continued)	Morone chrysops	2	380 318	820.0 420.0	1240.0	Epistylis
	Morone saxatilis	3	506 842 524	1810.0 8164.8 2190.0	12,164.0	
	Lepomis gibbosus	2			3.9	
	Lepomis macrochirus	1	121	28.0	28.0	
	Lepomis microlophus	1	122	29.0	29.0	
7 Feb 1977 (Electro-fishing)	Lepisosteus osseus	3			1585.0	
	Dorosoma cepedianum	27			4080.0	
	Cyprinus carpio	3			8025.0	
	Hybognathus nuchalis	23			96.9	Uvulifer (20)
	Notropis niveus	7			20.9	
	Notropis petersoni	20			30.1	
	Minytrema melanops	10			9740.0	
	Ictalurus punctatus	1	193	59.0	59.0	

Table 2 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
7 Feb 1977 (Electro-fishing) (Continued)	<u>Pylodictis olivaris</u>	2			31,298.4	
	<u>Morone chrysops</u>	8	336	460.0	2240.0	
			324	395.0		
			298	305.0		
			231	155.0		
			282	345.0		
			217	125.0		
			316	395.0		
			176	60.0		
	<u>Morone saxatilis</u>	2	606	2600.0	4780.0	
			520	2180.0		
	<u>Lepomis gibbosus</u>	1			9.0	
	<u>Lepomis macrochirus</u>	4	202	192.0	323.0	
			144	58.0		
			139	48.0		
			115	25.0		
	<u>Lepomis microlophus</u>	1	176	92.0	92.0	
	<u>Lepomis punctatus</u>	2	118	37.0	51.0	
			83	14.0		
	<u>Perca flavescens</u>	2			27.0	

a/ Numbers in parenthesis represent number of individuals <50 mm total length.

Table 3 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
26 Jul 1976 (Rotenone) (Continued)	<u>Lepomis</u> <u>macrochirus</u>	4	76	6.3	19.3	
			69	5.5		
			64	3.8		
			63	3.7		
	<u>Lepomis</u> <u>punctatus</u>	1	91	15.6	15.6	
	<u>Micropterus</u> <u>salmoides</u>	6	390	795.3	821.5	
			95	10.3		
			77	5.7		
			72	4.5		
			63	3.6		
			53	2.1		
	<u>Pomoxis</u> <u>nigromaculatus</u>	2	<50		2.2	
	<u>Etheostoma</u> <u>olmstedi</u>	2			1.0	
23 Aug 1976 (Rotenone)	<u>Lepisosteus</u> <u>osseus</u>	1			84.0	
	<u>Dorosoma</u> <u>cepedianum</u>	5			2335.0	
	<u>Hybognathus</u> <u>nuchalis</u>	5			3.5	
	<u>Notropis</u> <u>petersoni</u>	101			55.9	
	<u>Notropis</u> <u>maculatus</u>	2			0.4	

Table 3 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
23 Aug 1976	_Ictalurus punctatus_	27	561	2320.0	4906.4	
(Rotenone)			483	2012.6		
(Continued)			371	397.4		
			221	79.4		
			150	25.4		
			127	16.4		
			87	6.2		
			82	4.5		
			79	4.0		
			84	5.0		
			74	3.7		
			71	2.9		
			64	2.3		
			57	1.7		
			63	2.3		
			55	1.7		
			53	1.4		
			57	1.7		
			55	1.5		
			54	1.4		
			53	1.3		
			53	1.3		
			53	1.3		
			59	1.9		
			54	1.4		
			55	1.5		
			54	1.4		
		(6)	<50	4.8		

Table 3 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
23 Aug 1976 (Rotenone) (Continued)	*Pylodictis olivaris*	4			75.2	
	Lepomis sp.	6	≤50		4.2	
	Lepomis gulosus	3			17.2	
	Lepomis microlophus	4	136	38.9	103.2	
			137	39.8		*Lernaea*
			112	21.5		*Lernaea*
			55	3.0		
	Lepomis punctatus	1	79	10.3	10.3	
	Micropterus salmoides	3	138	31.7	36.9	
			62	3.0		
			56	2.2		
	Pomoxis nigromaculatus	2	137	26.2	41.9	
			115	15.7		
20 Sep 1976 (Rotenone)	*Dorosoma cepedianum*	9			2012.0	
	Dorosoma petenense	36			102.0	
	Notropis maculatus	1			0.4	
	Notropis niveus	14			11.9	
	Notropis petersoni	133			96.1	

Table 3 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
20 Sep 1976 (Rotenone) (Continued)	<u>Ictalurus punctatus</u>	26	416	617.0	1303.6	
			373	442.0		
			220	78.7		
			201	57.1		
			113	13.1		
			115	12.4		
			104	10.3		
			99	8.7		
			90	6.2		
			81	4.9		
			81	4.8		
			82	5.1		
			75	3.7		
			80	4.7		
			75	3.8		
			67	3.2		
			66	3.1		
			74	3.8		
			71	3.6		
			59	2.2		
			62	2.6		
			60	2.1		
			59	2.2		
			52	1.5		
			52	1.5		
			53	1.7		
		(5)	<50	3.6		
	<u>Pylodictis olivaris</u>	4			7.1	

Table 3 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
20 Sep 1976 (Rotenone) (Continued)	<u>Lepomis</u> sp.	11	< 50		17.2	
	<u>Lepomis gulosus</u>	1	96	16.6	17.1	
		(1)	≤50	0.5		
	<u>Lepomis macrochirus</u>	6	159	72.3	163.5	<u>Lernaea</u>
			134	45.3		
			111	23.5		
			98	16.6		<u>Lernaea</u>
			51	2.1		
			51	2.1		
		(1)	< 50	1.6		
	<u>Lepomis microlophus</u>	1	99	15.0	15.0	
	<u>Lepomis punctatus</u>	1	< 50		1.4	
	<u>Micropterus salmoides</u>	1	91	8.3	8.3	
	<u>Etheostoma olmstedi</u>	1			1.6	
3 Nov 1976 (Electro-fishing)	<u>Lepisosteus osseus</u>	1			340.0	
	<u>Dorosoma cepedianum</u>	2			135.0	
	<u>Cyprinus carpio</u>	2			6185.0	
	<u>Notropis niveus</u>	6			9.9	

Table 3 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
3 Nov 1976 (Electro-fishing) (Continued)	*Notropis petersoni*	2			3.9	
	Ictalurus punctatus	2	106 86	10.0 5.0	15.0	
	Lepomis punctatus	1	87	12.1	12.1	
29 Nov 1976 (Electro-fishing)	*Lepisosteus osseus*	5			3255.0	
	Dorosoma cepedianum	5			775.0	
	Cyprinus carpio	2			6890.0	
	Hybognathus nuchalis	27			75.1	*Uvulifer* (25)
	Notropis niveus	31			61.8	
	Notropis petersoni	56			80.8	
	Ictalurus punctatus	1	132	30.0	30.0	
	Lepomis auritus	2	152 116	75.0 35.0	110.0	
	Lepomis gibbosus	3			7.9	
	Lepomis gulosus	3			84.0	
	Lepomis macrochirus	12	236	285.0	945.5	*Epistylis*

Table 3 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
29 Nov 1976 (Electro-fishing) (Continued)	Lepomis macrochirus		156	85.0		
			184	150.0		
			132	55.0		
			188	155.0		
			127	50.0		
			117	35.0		
			165	90.0		
			116	22.5		
			80	6.5		
			74	5.1		
			74	5.3		
		(1)	<50	1.1		
	Lepomis microlophus	1	186	125.0	126.3	
		(1)	<50	1.3		
	Lepomis punctatus	4	108	21.6	56.8	
			97	16.5		
			78	9.3		
			76	8.0		
		(1)	<50	1.4		
	Micropterus salmoides	1	105	12.0	12.0	
29 Dec 1976 (Electro-fishing)	Lepisosteus osseus	3			525.0	
	Cyprinus carpio	1			2940.0	
	Hybognathus nuchalis	1			5.2	

Table 3 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
29 Dec 1976 (Electro-fishing) (Continued)	*Notropis niveus*	13			17.5	
	Notropis petersoni	10			13.1	
	Lepomis macrochirus	1	<50		0.4	
	Lepomis microlophus	1	73	7.1	7.1	
	Lepomis punctatus	3	109 83 60	23.0 9.0 3.0	35.0	
	Micropterus salmoides	2	127 101	21.0 11.0	32.0	
26 Jan 1977 (Electro-fishing)	*Lepisosteus osseus*	1			567.0	
	Cyprinus carpio	1			3628.8	
	Hybognathus nuchalis	1			4.7	*Uvulifer*
	Notropis niveus	9			17.5	
	Notropis petersoni	3			6.4	
	Minytrema melanops	1			1247.4	
	Morone chrysops	1	273	245.0	245.0	

Table 3 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
26 Jan 1977 (Electro-fishing) (Continued)	Lepomis macrochirus	1	111	27.0	27.0	
	Lepomis punctatus	1	122	42.0	42.0	
7 Feb 1977 (Electro-fishing)	Lepisosteus osseus	5			8456.8	
	Dorosoma cepedianum	12			605.0	
	Cyprinus carpio	1			3220.0	
	Hybognathus nuchalis	10			37.4	Uvulifer (10)
	Notemigonus crysoleucas	3			37.7	
	Notropis maculatus	2			1.1	
	Notropis niveus	14			32.1	
	Notropis petersoni	28			45.1	
	Minytrema melanops	4			3990.0	
	Ictalurus punctatus	1	350	360.0	360.0	
	Morone chrysops	2	296 307	335.0 355.0	690.0	
	Morone saxatilis	1	411	885.0	885.0	

Table 3 . (Continued)

Sampling Date (Method)	Species Collected	Total Number	Individual Lengths (mm)	Individual Weights (g)	Total Weight (g)	Parasitic Infestations
7 Feb 1977 (Electro-fishing) (Continued)	*Lepomis macrochirus*	3	148	60.0	95.3	
			115	28.0		
			77	7.1		
		(1)	<50	0.2		
	Lepomis marginatus	1			14.8	
	Lepomis punctatus	2	100	22.0	41.0	
			94	19.0		
	Micropterus salmoides	1	478	1685.0	1685.0	*Epistylis*
	Etheostoma olmstedi	1			3.2	

a/ Numbers in parenthesis represent number of individuals <50 mm total length.

APPENDIX C

Impingement Monitoring Data

Table 1 . Organisms collected from Wateree Station intake screens, January 1975 through March 1976.

Sampling Date	Organisms Collected	Number Collected	Size Distribution (mm)	Total Weight (g)
7-8 Jan 1975	Dorosoma petenense	82,830	≤77	149,820
23-24 Jan 1975	Dorosoma petenense	7,500	<102	13,620
	Esox americanus	2	95-102	30
6-7 Feb 1975	Dorosoma petenense	22,509	<102	54,934
	Dorosoma petenense	12	102-152	454
	Ictalurus sp.	1	64	5
17-18 Feb 1975	Dorosoma petenense	63,750	<77	115,770
	Dorosoma petenense	24	102-178	681
	Perca flavescens	5	95-108	78
	Esox americanus	2	133-229	116
	Lepomis gulosus	1	89	21
	Ictalurus punctatus	1	140	37
5-6 Mar 1975	Dorosoma petenense	15,003	<77	27,331
	Perca flavescens	1	89	9
20-21 Mar 1975	Dorosoma petenense	1,256	<89	2,337
	Dorosoma petenense	18	121-146	568
	Perca flavescens	45	77-114	682
	Ictalurus sp.	5	64-77	14
	Ictalurus sp.	1	184	59
	Lepomis sp.	1	83	7
	Aphredoderus sayanus	2	64	10
	Etheostoma sp.	1	64	4
	Asiatic clam	12	-	-
	Crayfish	1	-	-

Table 1 . (Continued)

Sampling Date	Organisms Collected	Number Collected	Size Distribution (mm)	Total Weight (g)
16-17 Apr 1975	Alosa sp.	2	140-152	71
	Dorosoma cepedianum	26	<89	227
	Perca flavescens	4	102-216	341
	Ictalurus punctatus	10	51-203	227
	Ictalurus sp.	3	51-152	52
	Ictalurus sp.	1	330	596
	Lepomis sp.	1	-	-
	Lepomis microlophus	1	95	27
	Centrarchus macropterus	1	112	43
	Tadpole	1	76	8
	Asiatic clam	20	-	-
30 Apr- 1 May 1975	Ictalurus punctatus	20	114-229	813
	Ictalurus sp.	11	152	356
	Dorosoma cepedianum	19	64-114	88
	Dorosoma sp.	8	114-254	457
	Perca flavescens	4	114	102
	Lepomis microlophus	4	38	7
	Lepomis sp.	2	89-140	110
	Ictalurus catus	1	64	4
	Asiatic clams	65	-	-
13-14 May 1975	Ictalurus punctatus	8	108-152	239
	Ictalurus sp.	2	102-121	32
	Lepomis microlophus	1	95	29
	Morone saxatilis	2	419-451	2,840
	Asiatic clams	70	-	-
28-29 May 1975	Dorosoma cepedianum	2	269-279	511

Table 1 . (Continued)

Sampling Date	Organisms Collected	Number Collected	Size Distribution (mm)	Total Weight (g)
28-29 May 1975 (Continued)	*Ictalurus punctatus*	15	76-178	341
	Amia calva	1	127	30
	Centrarchus macropterus	1	84	27
	Pomoxis annularis	1	121	61
	Greater siren	1	699	596
9-10 Jun 1975	*Ictalurus* sp.	2	165	–
	Dorosoma sp.	1	114	–
	Asiatic clam	58	–	–
26-27 Jun 1975	*Dorosoma cépedianum*	1	273	148
	Ictalurus punctatus	6	152	164
	Cyprinus carpio	1	76	12
	Lepomis sp.	1	38	1
	Asiatic clam	40	–	–
7-8 Jul 1975	*Morone saxatilis*	1	254	540
23-24 Jul 1975	*Ictalurus punctatus*	2	152	–
	Asiatic clam	30	–	–
4-5 Aug 1975	*Cyprinus carpio*	1	381	795
	Asiatic clam	60	–	–
20-21 Aug 1975	*Ictalurus catus*	1	279	256
	Ictalurus catus	2	≤51	2
	Cyprinus carpio	1	356	568
	Dorosoma petenense	5	<51	9
	Asiatic clam	35	–	–

Table 1 . (Continued)

Sampling Date	Organisms Collected	Number Collected	Size Distribution (mm)	Total Weight (g)
4-5 Sep 1975	_Dorosoma petenense_	7	≤51	6
	Ictalurus catus	1	76	7
	Ictalurus catus	1	203	116
	Asiatic clam	30	–	–
17-18 Sep 1975	None	–	–	–
2-3 Oct 1975	_Dorosoma petenense_	3	44	3
	Ictalurus catus	1	53	3
	Asiatic clam	80	–	–
15-16 Oct 1975	_Dorosoma petenense_	5	<51	7
	Asiatic clam	100	–	–
30-31 Oct 1975	None	–	–	–
11-12 Nov 1975	_Dorosoma petenense_	18	<51	18
	Asiatic clam	10	–	–
24-25 Nov 1975	_Dorosoma petenense_	375	<51	454
	Asiatic clam	10	–	–
10-11 Dec 1975	None	–	–	–
22-23 Dec 1975	_Dorosoma petenense_	12,060	<64	30,418
7-8 Jan 1976	_Dorosoma petenense_	14,820	<89	35,412
12-13 Jan 1976	_Dorosoma petenense_	7,927	51-127	20,430

Table 1 . (Continued)

Sampling Date	Organisms Collected	Number Collected	Size Distribution (mm)	Total Weight (g)
22-23 Jan 1976	*Dorosoma petenense*	23,650	44-146	48,805
27-28 Jan 1976	*Dorosoma petenense*	8,500	<51	38,704
	Anguilla rostrata	1	762	1,420
5-6 Feb 1976	*Dorosoma petenense*	1,620	<51	16,344
17-18 Feb 1976	*Dorosoma petenense*	2,535	<51	17,892
3-4 Mar 1976	*Dorosoma petenense*	98	51-89	141
	Asiatic clam	25	-	-
17-18 Mar 1976	*Dorosoma petenense*	14	<64	20
	Perca flavescens	4	83-95	38
	Perca flavescens	1	140	-
	Ictalurus catus	1	140	44
	Asiatic clam	15	-	-